DOCTOR OF PHILOSOPHY

A Study of Evaluation Methodologies and Impact of STEM (Science, Technology, Engineering and Mathematics) Outreach Activities

Bagiya, Yamuna

Award date:
2016

Awarding institution:
Coventry University

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By

Yamuna Bagiya

PhD

May 2016

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Yamuna Bagiya

May 2016

A thesis submitted in partial fulfilment of the University's requirements for the Degree of Doctor of Philosophy

Declaration of Authorship

This dissertation is the author's own work. Data or information from other authors that are referred to or quoted in the text is acknowledged at the approporatie point in the text.

Signed: ______________________________________

Date: ____

Abstract

It is expected that by 2022, an additional 2.5 million workers with science, technology, engineering and mathematics (STEM) skills will be required globally, although there is a shortfall of around 40,000 STEM graduates per year. Several strategies have been suggested to address this deficit, one of which includes providing STEM outreach activities for school pupils, including interactive STEM workshops, STEM ambassador presentations, master classes, competitions and talks about STEM careers. However, very little research has been conducted that has examined different perspectives and investigated approaches to enhance the delivery, impact and evaluation of STEM outreach. The purpose and significance of this research is to identify and develop an effective STEM outreach model that describes strategies to maximise the efficiency of outreach activities through combining the views of the receiver, facilitator and provider involved in STEM outreach.

This research utilised a mixed methods approach. Qualitative data were collected through semi-structured interviews with outreach facilitators (practitioners) and teachers specialising in a range of STEM subjects. Both qualitative and quantitative data were collected through surveys with students of different age groups. The research questions focused on STEM outreach practitioners' and teachers' perspectives on a range of areas including how students are selected, target year groups, evaluation methodology and factors influencing the impact of STEM outreach. The research also explores students' perceptions, understanding and aspirations of STEM subjects, careers and examines the evidence for differences based on gender, ethnicity and whether or not a student had participated in a STEM outreach activity.

The key messages that emerge from this study include the importance of dialogue between outreach practitioners, teachers and students. A second important finding is that messages about STEM are most effective by integrating STEM outreach into a school's ethos and providing all students with an equal opportunity to access the activities provided. Another important finding concerns students' views on preferred types of activities, which include fun and interactive activities. Gender, ethnicity and

participation in STEM outreach activities were found to have significant effect on GCSE and A level students' aspirations of a STEM career.

Conclusions from the research include the proposal that every student should be offered STEM outreach throughout their compulsory education, creating more opportunities to positively influence and inspire them towards STEM education and careers. It is suggested that a generic evaluation tool is developed in order to capture more rigorous and meaningful data. It is also identified that the STEM community should develop a STEM outreach Quality Framework and STEM outreach practitioners training qualification in order to ensure maximum interaction and impact on young people. Finally, to support planning and delivery for future outreach activities, a prototype model has been recommended as part of this research. If implemented, the enhanced provision of activities should help to effectively address the shortage of high quality STEM graduates and professionals.

Dedication

I dedicate this thesis to my parents, ***Kishor Bagiya*** and ***Sona Bagiya***. They have given me endless support and love and made many sacrifices so that I can be at the place I am at now. Their blessings are what has brought me this far and I hope I can continue to always work hard and make them feel proud.

On 8th of September 2016 my dad passed away due to his illness – I know completing this thesis and becoming *Dr. Yamuna Kishor Bagiya* made his the proudest dad ever. His willpower and positive outlook is what I will always hope to carry forward.

Dad I miss you and I love you a lot.

Acknowledgements

Firstly, I would like to express a heart-warming thank you to my supervisor, ***Dr. Farzana Aslam***. She has supported me in so many ways that are beyond what a supervisor would normally do. Along with her energy and efforts towards bringing the best out of me, her confidence and trust have given me the strength to keep going and produce the best thesis I could. I am very lucky to have her as my mentor and supervisor, and without her help and encouragement, this thesis would not have been written (or ever finished!).

Secondly, I would like to give a special thank you to ***Professor Duncan Lawson*** and ***Irene Glendinning*** for their advice, guidance and continuous support. They have given me their time, knowledge and valuable discussions to help develop my understanding of various aspects of this research.

My sincere thank you also goes to ***Dr. Arinola Adefila***. She has shared her expertise, by giving many helpful suggestions and comments on the qualitative analysis for this thesis.

I would also like to acknowledge the ***Faculty of Engineering, Environment and Computing at Coventry University***. Their financial support has allowed me to complete my PhD and gain valuable teaching experience, for which I am really grateful.

Finally, I would also like to thank my partner, ***Steven Dass***, who has been my strength during this journey. Without his countless attempts of making sure I'm happy, focusing on my work and reiterating 'nothing else matters', this journey would have been very difficult. Him taking me to Hawaii and asking me to be his wife (just before my submission!) was amazing, and I cannot wait to start my next chapter with him by my side.

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- Yamuna Bagiya, Farzana Aslam et al. **“Evaluation and Impact of STEM outreach activities – views of secondary school teachers”**, submitted to Journal of Education for Teaching.

- Yamuna Bagiya, Farzana Aslam et al. **“How much influence does STEM outreach activities have on the choice of subject by STEM undergraduate students”,** (In preparation).

- Yamuna Bagiya, Farzana Aslam et al. **“How much STEM outreach activities impact GCSE and A level students on the choices of A level subjects and degree programmes”,** (In preparation).

- Yamuna Bagiya, Farzana Aslam et al. “**Delivery, Impact and Evaluation of STEM outreach activities – views of practitioners”**, (In preparation).

Conference Presentations

- Yamuna Bagiya, **'Engaging, Supportive, Always learning' via effective small group teaching**, PgCert in Academic Practice in Higher Education, 10th July 2015, Coventry University
- Yamuna Bagiya and Farzana Aslam, **Impact of STEM Outreach and STEM Undergraduate students**, Department Internal Seminar, 27th May 2015, Coventry University
- Yamuna Bagiya and Farzana Aslam, **Impact of STEM Outreach and STEM Undergraduate students**, Annual Faculty Research Symposium, 6th May 2015, Coventry University
- Yamuna Bagiya, **Impact of STEM Outreach and secondary school teachers**, Educational Dialogue and Transformative Learning in STEM Subjects in Mexico and the UK workshop, 9th -13th February 2015, Tecnológico de Monterrey, Mexico
- Yamuna Bagiya and Farzana Aslam, **Effective Methodologies for STEM Outreach** BCME8 Building Bridges- Making Connections conference, 14th April 2014, University of Nottingham
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- Yamuna Bagiya and Farzana Aslam, **Effective Methodologies for STEM Outreach,** CETL-MSOR conference, 10th - 11th September 2013, Coventry University

Chapter 1

Introduction

1.1 Introduction

The Government of the United Kingdom has identified the uptake of science, technology, engineering and mathematics (STEM) subjects in further and higher education as a key factor in ensuring a successful future for the nation (HM Treasury, DTI and DfES 2004). There is a strong focus towards ensuring the next generation of graduates includes a substantial proportion with strong STEM skills. As studies show that a lack of STEM professionals can negatively affect the economy, innovation, research and development, and global competitiveness of the UK (Roberts 2002; HM Treasury, DTI and DfES 2004). A recent study by Engineering UK (2015) predicts that by 2022, an additional 2.5 million workers will be required from the engineering related sectors. As the demand for graduates with STEM skills continues to grow, it is estimated there will be a shortfall of around 40,000 STEM graduates per year (Broughton 2013).

To overcome this global problem, there is a great emphasis on increasing students' interest and understanding of STEM subjects, as well as awareness of the opportunities opened by a STEM qualification. Students' lack of awareness of careers (especially from girls and ethnic minorities) has been shown to negatively impact on their subject choices made beyond GCSE, and as a result, fewer students than required are found studying STEM subjects at A level and in higher education (Broughton 2013).

A key approach to promoting the uptake of STEM degrees has been the development of enhancement and enrichment outreach activities for young people (Packard 2011), largely driven by Higher Education Institutions. The purpose of these activities is to enhance students' learning of STEM topics in a range of ways, such as after school clubs, challenges, competitions and STEM ambassador programmes.

My research focuses on the impact and evaluation of STEM outreach activities, highlighting and recommending key findings essential to improving the impact made on GCSE, A level and university undergraduate students' understanding and awareness of STEM subjects and careers. I have explored the three key contributors involved: the outreach practitioners who are the providers that deliver outreach, the students who experience outreach (aged 14-19) and the school teachers who are the key link between the provider and the receiver of STEM outreach. Whilst exploring them independently, their views and experiences are also combined to gain a deeper understanding of the complexity of their relationship (Creswell 2007).

The primary focus of the investigation with the students was to conduct a comparative analysis between students who had participated in STEM outreach and those who had not, in order to measure the differences in their level of understanding of STEM subjects and careers, as well as their aspiration for a STEM career. The objective of interviews, with the practitioners and the teachers, was to gain a deeper understanding of their role as a provider and coordinator and thus explore their wealth of knowledge, views and experience as an insider observer involved in STEM outreach. Therefore, this study evaluates and identifies the effectiveness of STEM outreach from different perspectives and describes the relationship between the different stakeholders.

1.2 Background to the research

Developing a skilful workforce that helps to achieve long-term sustainable economic growth remains a universal desire. However, creating a country that is equipped for future high valued jobs is a worldwide challenge. As a result, the United States, along with other developed and developing countries have identified STEM education reform as a strong economic policy agenda (Fan and Ritz 2014). This strategy supports many key purposes which are needed for global competitiveness. It can produce high levels of productivity, research and development activities as well as advancement of scientific and technological innovations (National Science Board 2015). Thus, many political and business leaders, including President Barack Obama, have acknowledged the prominence of STEM employment and education and reinforced the necessity of developing creative and innovative thinkers for revolutionising the landscape of the world.

“Science is more than a school subject, or the periodic table, or the properties of waves. It is an approach to the world, a critical way to understand and explore and engage with the world, and then have the capacity to change that world..."

— President Barack Obama, March 23, 2015

Since the early 1800s there have been ongoing concerns about the workforce employed in the field of STEM (Ostler 2012), and globally many more prepared and highly trained people are needed to join the STEM workforce, which is critical for a sustainable economy. In order to increase economic performance as well as the pool of talent entering STEM, a strong focus is given towards students’ education. To support this view, a study by OECD (2010) investigated the association between improvements in the average scores on PISA tests with economic growth and found a correlation such that low scores in mathematics and science indicated shortfalls in economic performance relative to economic possibilities. Nevertheless, a study conducted by the World Economic Forum (2013) investigated the quality of mathematics and science education and found countries such as the US and the UK were low, as 49th and 50th out of 148 countries respectively (Adonis 2014), hence, demonstrating the importance of focusing on STEM education and the workforce.

1.3 Purpose and significance of the research

There is a dearth of scholarly work in the area of evaluating the impact of STEM outreach. Of the small number of such studies, many have focused on single STEM subjects, or on two of the three key contributors, or investigated the impact and evaluation of STEM outreach from an individual perceptive only (for example, Archer 2013; Atkins 2013; Thorley 2014). A study by Wynarczyk and Hale (2009) supported this view by highlighting the limited number of studies that provide evidence and evaluation of STEM initiatives. Nevertheless, several studies have identified the need to effectively support the goal and vision of increasing the future supply of qualified STEM professionals and addressed areas of improvement in the provision of STEM outreach (DfES 2004; Rammell, Adonis and Sainsbury 2006; Moore, Sanders and Higham 2013).

Thus, the purpose and significance of this study is to identify and develop a STEM outreach model that helps to describe strategies to maximise efficiency in its impact, delivery and evaluation through combining the views of the receiver (students aged 14-19), facilitator (secondary/college teachers interested in STEM) and provider (professional institutions and higher education university staff members) involved in STEM outreach.

Packard (2011) reported the importance of this, as by advocating a “sustainable, coordinated approach to outreach” the impact of STEM outreach is “strengthened”. This current study aims to support these goals through gaining a detailed and comprehensive understanding of the facilitator’s and provider’s wealth of knowledge and experience of coordinating, delivering and evaluating STEM outreach, as well as investigating the impact of participating in outreach activities from the receivers’ (students’) point of view.

This study has gathered primary data from outreach practitioners from all backgrounds (including those in academia and industry from various STEM disciplines), teachers (that provide and organise internal and external outreach events for a range of STEM subjects) and students (at three different transition points; studying their GCSEs, A levels and undergraduate STEM degrees). Furthermore, differences between key factors such as gender, ethnicity and socio-economic background are investigated.

This study aims to recommend approaches that will maximise the efficacy and impact from a STEM outreach experience and help classify strategies to improve the interaction and relationship between the provider, facilitator and receiver of STEM outreach. Therefore, through this research, I aim to contribute towards addressing the shortage of well-qualified trained STEM graduates and professionals and so increase the flow of people going into the STEM workforce through positive and impactful outreach efforts.

1.4 Outline of thesis

The thesis consists of seven chapters. Starting with an introduction, a detailed literature review on STEM outreach is presented in Chapter 2, which is broadly split into two main sections: STEM workforce and STEM outreach. Thereafter, Chapter 3 discusses the relationship between the three key stakeholders involved in STEM outreach, presents the research questions and provides a thorough description of the methodological approach chosen for this study. The following Chapters 4, 5 and 6 report the in-depth qualitative and quantitative results collected from the STEM outreach practitioner, teacher and student data analysis respectively. This then concludes with Chapter 7, which discusses the results and conclusions, and provides key recommendations and implications that can be taken further for future study. An illustration of the structure of the thesis is shown below in Figure 1.1.

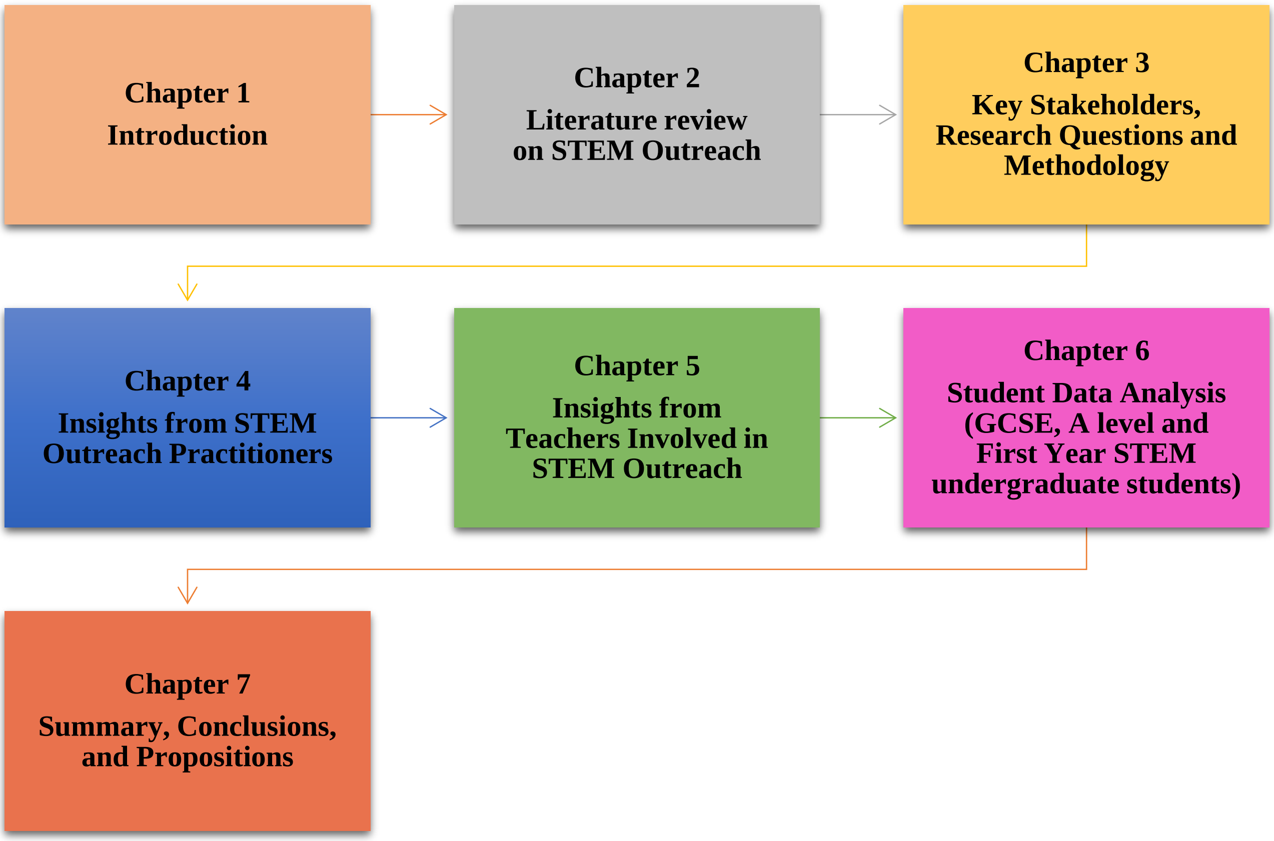

Figure 1.1: Outline of thesis

Chapter 2

Literature Review on STEM Outreach

2.1 Introduction

This chapter provides a detailed literature review on the shortage of STEM professionals, highlights the impact of this shortage, and discusses the current strategies implemented to address this issue. A detailed literature review of STEM outreach is also presented which includes the key purpose and stakeholders involved in outreach, as well as the impact of STEM outreach. The topics covered in this chapter are outlined below in Figure 2.1.

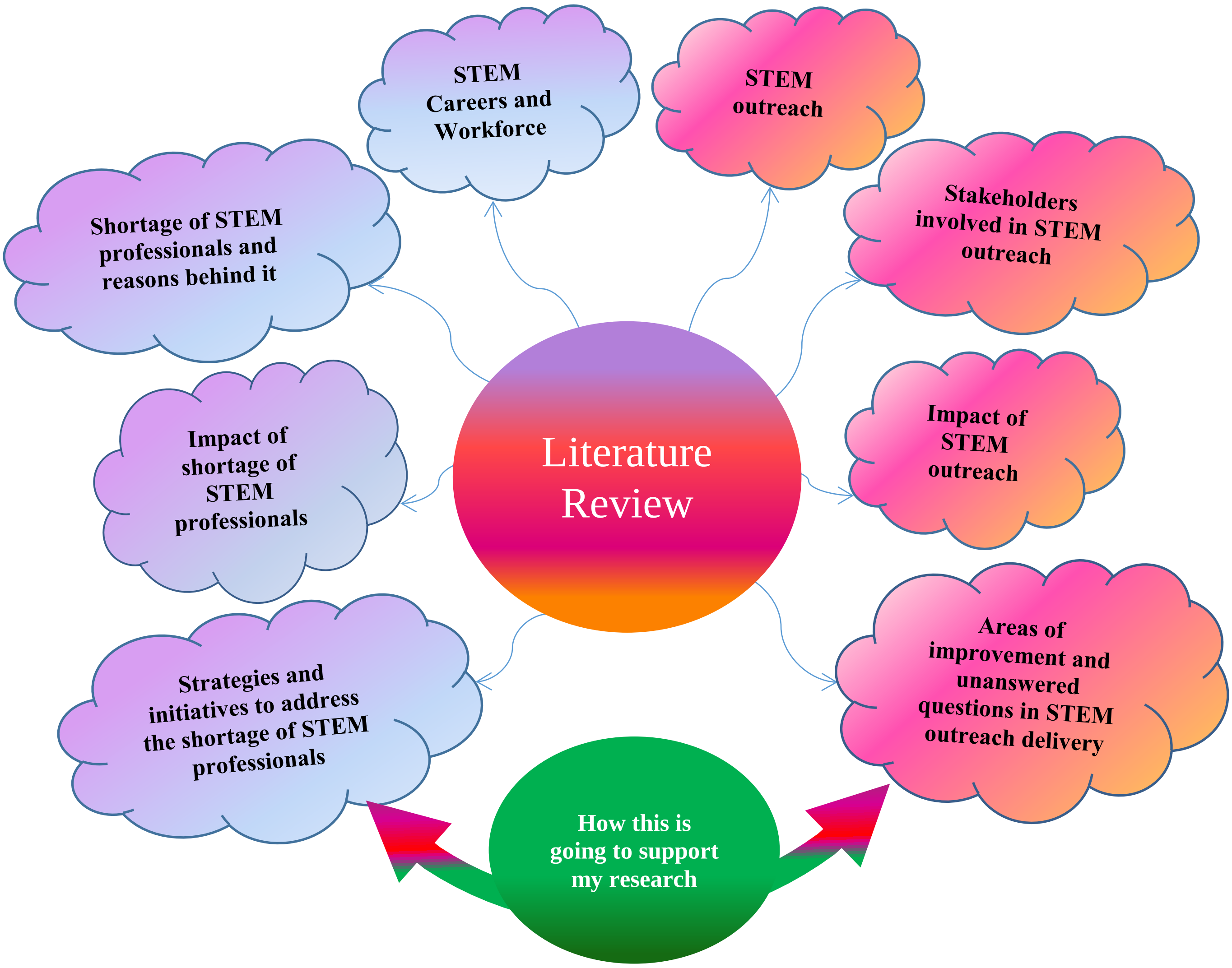

Figure 2.1: An illustration outlining the key areas that support this research

2.2 STEM workforce

Professionals working in the area of science, technology, engineering and mathematics (STEM) form the STEM workforce and contribute to economic growth, productivity, research and development, and innovation (HM Treasury, DTI and DfES 2004; UKCES 2011; Sainsbury 2007). The National Science Board (2015) has defined the STEM workforce as:

“The STEM workforce consists of many types of STEM-capable workers who employ significant STEM knowledge and skills in their jobs. This workforce includes the scientists and engineers who further scientific and technological progress through research and development (R&D) activities, workers in non-R&D jobs who use STEM knowledge and skills to devise or adopt innovations, and workers in technologically demanding jobs who need STEM capabilities to accomplish occupational tasks”.

To be part of this workforce requires STEM knowledge and skills, which are developed from studying core components of STEM subjects, stimulating the process of critical thinking and developing the capability of applying knowledge through creative approaches to solving complex problems (Ffiseg and Nghymru 2010).

The UK Commission for Employment and Skills (UKCES) in 2014 conducted a study titled *Future of Work* and outlined key trends that will require a significant level of STEM skills and knowledge for future occupations in the UK until 2030, as shown in Figure 2.2 (Störmer et al. 2014).

These trends can “shape the future” of jobs and skills essential for a competitive economy and, as a result, great importance is given towards graduates studying STEM subjects developing specific sets of skills required to address and meet the challenges of the future (Störmer et al. 2014).

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Figure 2.2: Occupations with a significant requirement for STEM knowledge and skills
Source: UKCES research by Störmer et al. 2014

2.2.1 STEM careers

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Source: 2010 Standard Occupational Classification (SOC) System, SOC Policy Committee recommendation to the Office of Management and Budget. Healthcare occupations are not included.

Figure 2.3: List of STEM occupations subject to occupational groups

A career in STEM is rewarding as well as challenging (BLS 2014). The graduates of STEM disciplines benefit from a higher salary and overall have better job prospects, as well as face challenging experiences. Figure 2.3 (BLS 2014) highlights many of the several careers contributing to the STEM workforce.

2.2.2 Shortage of STEM professionals

The current and future demand for STEM professionals in high valued jobs continues to grow as it drives factors such as employment, economic growth, competitiveness and innovation (Broughton 2013; Kumar, Randerson and Johnson 2015; Sainsbury 2007). The House of Lords Science and Technology Select Committee (2012) acknowledge this as they state “the UK desperately needs engineers, for example, to help grow the economy”. In addition, there is a high demand for qualified STEM graduates from both businesses and employers in STEM and non-STEM sectors due to the impact made by an employee with STEM qualifications, skills and knowledge. However, as the demand increases, especially for professionals in engineering and technology sectors, Broughton (2013), in her report states that domestic supply of STEM graduates is likely to remain low, with an estimated annual shortfall of around 40,000 graduating from STEM disciplines. Basing their calculations on the figures set out by the Royal Academy of Engineering and Big Innovation Centre, they reported a demand for around 104,000 new STEM graduates each year between 2013 and 2020. Thus, if we were to meet the demand, the supply of students graduating from STEM disciplines would need to be considerably higher.

A report conducted by Engineering UK (2015) stated that there were 5.4 million engineering professionals employed in the UK workforce (Kumar, Randerson and Johnson 2015). Whereas, Working Future, which generates the UK workforce demand forecasting figures, suggest that from 2012 to 2022 the UK would need an estimate of 2.56 million new engineering workers, of which 257,000 will be required to fill the vacancies from the creation of new jobs, with the remainder replacing those who retire or otherwise leave the engineering sector. They further state, if the demand is not met, a cost to the UK economy of £27 billion per year is expected (equivalent to building

1,800 secondary schools or 110 new hospitals). However, according to their calculations the demand does exceed the supply of engineering graduates, as their estimation of opening 163,000 new vacancies per year (107,000 at Level 4+ and 56,000 at Level 3) suffers an annual shortfall of 25,000 graduating with a Level 4+ (similar to Foundation Degree or Higher National Diploma) qualification and 30,000 with Level 3 (similar to A level qualification).

This reflects the current outlook on the shortage of STEM professionals and to support this, a review by John Perkins (2013) stated “given the rapid technological change we are facing, STEM skills are especially vital”. In addition, as the technology workforce grows rapidly it is also in high demand, as Tech City UK CEO, Gerard Grech (2015), states “the UK tech scene is growing and with it the prospects for anyone who wants to pursue a future in this rapidly evolving sector”.

Currently, 1,726,000 people are employed in the technology sector and at present 5% of the total UK workforce is part of this industry, which last year contributed over £91 billion to the UK economy (Tech Partnership 2015). Digital technology, which is also part of this workforce, has been growing such that by 2020, as part of the Government’s Digital Inclusion Strategy, it aims to develop all to become digitally capable (House of Lords Select Committee on Digital Skills 2015). However, due to advancement in technology a challenge addressed by Deloitte (2014) was the risk of losing an estimate of “35% of today’s jobs”. This study, in collaboration with the University of Oxford, found those who earned less than £30,000 per year were highly affected by this. Nevertheless, as the Select Committee on Digital Skills (2015) detail, “digital technology is changing all our lives, work, society and politics. It brings with it huge opportunities for the UK, but also significant risks”. As they highlight the shortage of these skills, the white paper by TechUK (2015) addresses the importance of foundational, creative application and specialist digital skills and provides suggestions on ways of closing this skills gap.

Research led by the Science Council (2011) found the number of people employed in a science-based role was 5.8 million, which included workers that were in pure science-based job and others that were in science related jobs which require a mixed application of scientific knowledge and skills alongside other skill sets. According to their study, this was equivalent to 20% of the UK workforce employed in science-based roles and employment figures in science by 2030 were projected to rise to 7.1 million (TBR 2011).

Several reports have detailed their forecasted figures such that a complex representation of the demand and supply of STEM professionals is shown as factors taken into consideration for each, having perhaps not always been consistent across the board. Despite this, collectively a key message is reported that there is a shortage of STEM professionals and graduates, especially in the area of engineering and computer science. In order to gain a comprehensive understanding of the lack of engineers and computer scientists, in particular, an overview outlining key findings from various reports is presented (see Table 2.1 and 2.2).

Shortage of Engineers	
Key Findings	References
• During 2012 and 2020, the UK economy will require over 100,000 scientists, engineers and technologists per year (in total an estimate of 830,000 professionals and 450,000 technicians) • There are multiple routes to an engineering profession (academic and vocational)	Harrison 2012
• High demand for engineers and their skills as well as their science and mathematical knowledge • Long-term supply - Prepare UK's young people with engineering skills, invest in science and mathematics education • Short term supply - Maintain retention rate (e.g. career breakers)	Perkin 2013
• High demand for engineering (and IT) professionals • Annual shortfall of around 40,000 STEM graduates • Provide greater importance towards improving GCSE results • Shortage of STEM skills remains even if the gap across gender of those studying STEM subjects beyond GCSE closes	Broughton 2013
• Required rise in public understanding and perception of engineering and engineers • Between 2010 and 2020, engineering companies are projected to have 2.74 million job openings - representing 19.8% of all job openings across all industries • 1.86 million workers are potentially likely to need engineering skills • Over the next 10 years, the UK will need an estimate of 87,000 people per year to meet demand for 865,100 graduates • Supply of around 51,000 graduates produced each year that is able to go into engineering occupations	Kumar, Randerson and Kiwana 2013
• UK's engineering workforce employed 5.4 million people in 2014 • 2.5 million workers will be needed by 2022 • 257,000 graduates are required to fill new vacancies • Estimated opening of 163,000 new vacancies per year • Annual shortfall of 25,000 graduating with a Level 4+ qualification and 30,000 with Level 3	Kumar, Randerson and Johnson 2015

Table 2.1: Overview of findings on the shortage of engineering professionals

Shortage of Computer Scientists	
Key Findings	References
• Demand for digital literacy • Shortage of medium and high level digital skills • 35% of the UK jobs estimated at risk of being automated over the next 20 years • Focus on internet accessibility and becoming digitally capable by 2020 • Develop digital and technology skills in addition to numeracy and literacy (make it a requirement) • Government should develop an ambitious Digital Agenda for the UK	House of Lords Select Committee on Digital Skills 2015
• The IT and Telecoms industry, which employs one in 20 of the workforce, is predicted to grow nearly five times faster than the UK average, with more than half a million new entrants required between 2012 and 2017 • Nine out of 10 firms are suffering IT and telecoms related shortages, which is delaying the development of new products and services	Bacon and MacKinnon 2013
• By the year 2015, there will be an estimate of 148,200 gross job opportunities in the UK's IT & Telecoms industry • 129,000 new entrants a year are required to fill IT & Telecoms job roles in the UK	e-skills UK 2012
• The president of the British Computer Society (BCS), Professor Nigel Shadbolt, told BBC News 'the computer industry faces a skills crisis'	Ghosh 2006
• Demand for graduates in computing remains strong • Since 2001, the number of students starting computing courses in higher education has fallen by more than 40% • If action is not taken - the UK's strength in computing research and industry could evaporate by 2020	BCS 2007
• 134,000 new skilled technology specialist workers are needed in the UK workforce every year • 14,000 young people sat a computing or ICT A level in 2014 • Fewer than 3,000 technology apprenticeships were advertised in 2014 • A shortage of skilled workers has its roots early on in the education system • There is a strong link between digital skills and creativity	Cox 2015
• Growth in demand for digital content and services, in particular, is expected to drive expansion of the digital and creative sector • The sector is expected to need 1.2 million new workers between 2012 and 2022, to both support growth and replace those leaving the sector. This is equivalent to half the current workforce	UKCES 2015

• There are particular concerns about the ability of the education system to supply the quantity and quality of workers needed for digital roles	
• There were approximately 31m people working in the UK in 2015 of which 1.8m (6%) were working in the tech sector – 1.1m (62%) within tech businesses (in tech or support roles) and a further 0.7m (38%) working as tech specialists within other parts of the economy	Tech Partnership 2016

Table 2.2: Overview of findings on the shortage of technology related professionals

In order to increase the number of professionals employed in the STEM workforce, there is a strong requirement of nurturing the future supply of graduates with STEM competency and skills throughout the education sector. The Social Market Foundation (2013) highlights this and further recommends providing greater attention towards increasing the pipeline of qualified STEM graduates, and the uptake of pre- and post-16 mathematics and science qualifications (Broughton 2013). The Confederation of British Industry (CBI) (2014) has also signified the importance of forming a STEM-skilled workforce through improvements in science and mathematics education. They proposed that a longer-term resolution requires increasing the uptake of STEM subjects beyond GCSE and, therefore, the supply of qualified STEM graduates and STEM professionals can be raised. To support this, an approach suggested by Broughton (2013) was to attempt "reducing the proportion of students lost to non-STEM subjects at each educational transition point". Thus, in order to gain a better understanding on the uptake of STEM subjects through all levels of education, the number of students studying undergraduate, post-16 and GCSE STEM related subjects is discussed below.

Observing the trends provided by the Higher Education Funding Council for England (HEFCE) (2015) from over a decade, overall there has been an 11% increase in the number of full-time undergraduate students in STEM related subjects. In 2002-03, there were 261,824 STEM graduates, which over the years have risen to 291,876 graduates studying STEM subjects in higher education (2013-14). However, this increase has been subject dependent and has shown a decline in the number of students studying computer science courses. Since 2002-03, the number of graduates has fallen from 77,527 to

47,468 and so there is a decrease of 39% over an eleven year period. The other STEM courses (see Figure 2.4) over the period 2002-03 to 2013-14, on average, have shown positive trends of growth, indicating a slow but steady change towards the desired outcome of more qualified STEM graduates.

Figure 2.4: Number of full-time undergraduate students in STEM related subjects
Source: Higher Education Funding Council for England (HEFCE 2015)

Over the 12 years, the uptake of undergraduate students in engineering and technology increased by 12% whereas for biological science and mathematical science related courses the uptake increased by almost 50%.

Students' post-16 options play a crucial role in progression to STEM at higher education and thus understanding the trends in the uptake of post-16 STEM subjects is crucial. Table 2.3 highlights the change over a ten year period, in the number of students studying a post-16 A level qualification in various STEM subjects.

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Table 2.3: Number of entries for A level STEM subjects

Source: Joint Council for Qualifications (JSQ)

Over the ten year period from 2005 to 2014, Mathematics has continued to be the most popular STEM subject for A levels. This, according to Vorderman's report (2011), was at its peak after 20 years in 2010 and has continued to increase since then, sustaining its position with 88,816 entries. The subject A level Further Mathematics has had the largest growth of 136.4% to over 14,000 entrants in 2014. In comparison to Chemistry and Biology the number of students who have opted to study A level Physics remains low (36,701 entries). Vorderman et al. (2011) suggest mathematics and science subjects are amongst the hardest A levels and yet the entry numbers for Mathematics, Further Mathematics, Biology, Chemistry and Physics have increased over the ten year period indicating a sign of positive change towards achieving a rise in the uptake of core STEM subjects. However, the total entrant numbers for A level Computing and ICT were 13,650 which over the decade has dropped substantially (42.4% and 36.3%

respectively) and, therefore, has caused a domino effect on the graduate numbers in IT and computer science courses.

Vocational qualifications in STEM subjects form another route to higher education and are believed to be “a significant part of the 14-18 education landscape” (Kumar, Randerson and Kiwana 2014). They have the potential to support the shortage of STEM skills as they provide young people with an opportunity to develop key skills that are required by engineers and technicians in the STEM workforce (Perkins 2013). A review commissioned by Adonis (2014) showed the importance of increasing the number of young adults taking apprenticeships. He strongly viewed this as a way forward to “solving the mismatch between the skills on offer” and the demand for technician-level competency, particularly for roles requiring science, technology, engineering and mathematics (STEM) skills. Nevertheless, the Wolf review (2011) found an estimate of at least 350,000 young people aged between 16 and 19 that were not benefiting from their involvement in such qualifications, which led to recommendations for key changes that supported reforming the provision of vocational qualifications for 16-19 year old students.

Students during their GCSEs are at “a critical point in the system”, though many students from this pipeline are not progressing further into post-16 STEM subjects. Therefore, targeting students at GCSE level could potentially “contribute to making up some of the shortfalls in STEM graduates” (Broughton 2013).

2.2.3 Underrepresented groups in the STEM workforce

To effectively address the demand for STEM professionals requires fully utilising the skills across the whole population, and so attracting talent from underrepresented groups is a key target. Therefore, maintaining a diverse workforce through widening participation in STEM is critical as it “has the potential to benefit businesses, maximise individual opportunity, and meet a national economic need” (CaSe 2014).

2.2.3.1 Female underrepresentation

Many studies have emphasised the importance of unlocking the skills and talent of women as a way forward towards reducing the shortage of STEM professionals (Greenfield et al. 2002; HM Treasury, DTI and DfES 2006; Sainsbury 2007; Broughton 2013; House of Commons Science and Technology Committee 2014; Macdonald 2014).

Women in Science and Engineering (WISE) (2015b) using the Labour Force Survey has evaluated the recent numbers of women employed in STEM occupations (see Figure 2.5). They found from 2014 to 2015 this has increased by 15% to 793,437, which meant 14.4% of women were currently representing the UK STEM workforce. However their results show improvements in various areas of STEM, including a rise in the number of women working in engineering (+ 45%) and ICT (+ 35%), as well as science and engineering technicians (+ 11%) and also in the number of women working in STEM management positions (+ 25%). Although the percentages look impressive, the numbers are still very low, as can be seen in the following Figure 2.5.

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Figure 2.5: Overview of women as STEM professionals

Source: WISE 2015b

The House of Commons Science and Technology Committee (2014) and many others have addressed the urgency of increasing the number of women employed in STEM and called this the "leaky pipeline". An overview of key findings that have highlighted the lack of women represented in UK's STEM workforce is presented in Table 2.4.

Shortage of Females in STEM professionals	
Key Findings	Reference
• Less than a fifth (17%) of STEM professors are women • The UK companies are missing a huge talent pool with many women finding it too difficult to progress, or those that are successful offered more attractive positions overseas • The UK economy needs more STEM workers and we cannot meet the demand without increasing the numbers of women in STEM • Lack of gender diversity in STEM is the result of perceptions and biases combined with the impracticalities of combining a career with family	House of Commons Science and Technology Committee 2014
• Seven in ten girls said they were interested in a career in STEM • Girls are interested in STEM, but the UK still only uses half of nation's brains • Nine in ten girls were unaware that an apprenticeship can lead to a career in STEM • One in five (19%) female university students who didn't pursue a STEM career said they just didn't know how to get a job in the sector • One in three (35%) women working in STEM said they had considered leaving the sector, with over half (51%) of this group pointing to barriers to career progression • The perception of girls not being interested in STEM is a myth. They are interested and aware that it is a wise career move, but still do not understand how to make it in the sector	Adecco 2015
• 17% of people employed in tech specialist roles are women, compared with 47% of the UK workforce as a whole	Tech Partnership 2015
• There are currently 2.4 million women who are not working and want to work • There are over 1.3 million women who want to work more hours • By equalising men and women's economic participation rates, we could add more than 10% to the size of the economy by 2030 • Women should not just try to fit into the economy, they should be shaping the economy • Girls outperform boys in education but this is not always reflected in	Women's Business Council 2013

their subsequent career aspirations or economic success • Fewer women are enrolled in STEM subjects at university (13% in engineering, 18% in technology and 22% in mathematics and computer science), whilst women make up 89% in nursing, 85% in education, 73% in linguistics and classics and 72% in languages and literature	
• From an already low base, female representation within both the IT professions and the IT sector have declined slightly over the past 10 years • By 2013, of 1,129,000 people working as IT specialists in the UK, less than one in six (16%) were women • Of the 753,000 people working in the IT sector at this time, just one in five (20%) were women • In 2013, within the IT sector itself little more than one in ten (11%) IT specialists were women • The proportion of women working as self-employed IT specialists has more than doubled in the past decade • Just under one in five (18%) of females working as IT specialists were employed on a part-time basis – a figure well below that for other occupations • The gender divide starts early in the ICT education system	e-skills UK, BCS and The Chartered Institute for IT 2014
• Women currently make up 46% of the UK's workforce, but just 15.5% of the core STEM workforce • Particularly underrepresented in engineering, where 8% of engineering professionals are females	CBI 2014
• 300 women working in engineering were surveyed • It is a myth that universities require students to study A level physics to do an engineering degree at university - there are now wider ranges of entry requirements such as engineering foundation courses • Engineering students are second only to medics in securing full-time jobs and earning good salaries • Yet the proportion of women in engineering courses is extremely low – just one in seven (the lowest for all university courses)	Atkins 2013
• Study on improving the participation of women in science and engineering provided the Government with strong and strategic approaches towards tackling the underrepresentation of females in science, engineering and technology (SET) occupations • Women's employment in SET related jobs has increased by nearly 30 percent between 1992 and 2000 – from 50,000 to 65,000. • Men's employment in SET related jobs has increased from 344,000 to 404,000 (17%) over the same period	Greenfield et al. 2002

• 5.3% (674,000 women), or about one in twenty, of all working women are employed in any SET occupation, compared to 31.3% for all working men (nearly one in three), in a total of 5.5 million women and men in SET occupations	Kirkup et al. 2010

Table 2.4: Overview of findings on the shortage of females in STEM professions

Although in recent years, there have been more positive indicators of women progressing further in STEM occupations than previously, the low overall figures remain a cause for concern. The rate of change and the proportion of women present in the total UK STEM workforce (14.4%), particularly in engineering and computing, does not appear to satisfy the demand of qualified STEM graduates required in the near future. Therefore it is important to work towards achieving a fair representation of women in the STEM workforce as well as nurturing the underutilised talent of women at all stages of education (CBI 2014).

Mathematics and science are the core subjects that are needed to study many STEM related subjects in higher education (Kiwana, Kumar and Randerson 2011). Thus, raising the entrant numbers of females studying those subjects at GCSE and A level along with their performance levels can impact the graduate progression route to higher education STEM subjects and careers. Currently, girls continue to do better than boys in STEM subjects at GCSE level (Kumar, Randerson and Johnson 2015). However a serious gender imbalance arises during A level and in higher education. There is a wide difference in females and males selecting subjects such as physics and mathematics in particular (Roberts 2002; Perkins 2013), though this has predominantly been the case for those girls that are from state-funded, co-educational schools than single-sex schools. A study conducted by the Institute of Physics (IOP), *"It's Different for Girls"* (2012), explored the influence of the type of school and found in 2011 that almost half (49%) of co-educational schools sent no girls to study A level physics. For over 20 years, physics has remained the least popular A level subject amongst many girls, representing an estimate of 20% of those studying this subject at post-16 level (Institute of Physics 2012). Nevertheless, Engineering UK (2015) illustrated the number of GCE

AS level A-C passes by gender and found in 2014, there were 23.7% female entries made for AS level physics and 39.4% for AS level mathematics, an improvement from the year 2013 (Joint Council for Qualifications 2015). As a result, the number of applications by females to study an engineering degree in higher education has been consistently low (Engineering 2015). Students' subject choice at GCSE and post-16 are a key barrier to women progressing in STEM higher education courses and employment (Perkins 2013).

2.2.3.2 Underrepresentation of ethnic minorities

The UK population currently is made up of White as well as Black and minority ethnic (BME) groups and people from BME are a substantial and fast-growing part of the population, with an expected growth of around 20–30% by 2051 (Sunak and Rajeswaran 2014).

A report conducted by UKRC (2010) reported the growth of BME groups in the STEM workforce; they found that in 2008 that BME women (8.2%) were more likely to work in SET occupations compared to White women (5.1%). However, the opposite was true for men as their findings suggested BME men (22.6%) were less likely to work in STEM than White men (32.2%) (Kirkup et al. 2010). In addition, a recent study *"Not for people like me?"* investigated the underrepresented groups in science, technology and engineering and found BME groups were overall well represented in STEM and in higher education (Macdonald 2014). Furthermore, a report by the Royal Society (2014) found BME were overrepresented, in particularly in the most senior and junior parts of the UK scientific workforce, though with a slight exception for Black and Black British people who were marginally underrepresented in the most senior roles. They further reported that the UK scientific workforce presented a complex representation of ethnicity making it difficult to draw firm conclusions.

The importance of diversity in STEM employment as well as education has been emphasised in several reports and, therefore, an overview is presented in Table 2.5 outlining the key findings on the issues around ethnicity in STEM.

Underrepresentation of ethnic minorities	
Key Findings	References
• The pattern of ethnicity in the scientific workforce is extremely complex • Overall in the scientific workforce, black and minority ethnic workers are relatively concentrated at the two ends of the spectrum – they are overrepresented in the most senior and most junior parts of the scientific workforce • Black and Black British people are slightly underrepresented in the most senior roles and other ethnic groups, most notably Chinese, are overrepresented in the most senior roles • For the mid-career cohort, people from White ethnic backgrounds were 1.5 times more likely to have worked in science at some stage of their careers so far than those from Black or minority ethnic communities	The Royal Society 2014
• One in five (20%) of female IT specialists are considered to be from non-white ethnic groups, a higher proportion than that for male IT specialists (15%) and when compared with the workforce as a whole (10%) • Amongst these non-white female IT specialists, just over half (52%) classed themselves as Indian	e-skills UK, BCS and The Chartered Institute for IT 2014
• The proportion of all BME women working in STEM occupations is increasing faster than the proportion of White women working in STEM occupations • Although similar proportions of white and BME women obtained undergraduate and postgraduate qualifications in STEM, BME women are more likely to then go on to work in STEM occupations • BME women were 14.4% of all BME engineering professionals, compared to only 6.3% of White women among White engineering professionals • Science and engineering professions were more popular among BME than White women	Kirkup et al. 2010
• In 2009/10 British students from a Black, Asian and Minority Ethnic (BAME) background accounted for 19% of all students studying STEM related subjects at UK universities • Russell Group universities make a major contribution to the supply of STEM-qualified graduates in the UK	Race for Opportunity 2011
• BME students are more likely to study STEM • BME students are more likely to choose maths, physics and chemistry A levels and aim for vocational degrees than white British students	Macdonald 2014

with the same GCSE levels • BME students are more likely to attend university by the age of 19 • Female Black African students made up a quarter of the cohort of women in STEM subjects while for men the equivalent figure was 21% • Computer science has a higher uptake by BME students and the percentage of BME students is slowly increasing across many other STEM subjects including physical science and engineering and technology	
• At GCSE, attainment has improved for students from different ethnic backgrounds and for students who speak English as an additional language • Since 2007, there have been big improvements in the performance of students from different ethnic backgrounds • At GCSE, all of the main ethnic groups have increased their levels of attainment, with Bangladeshi students making the greatest gains over time • Overall, Chinese and Indian students continue to perform more strongly than other ethnic groups. Their attainment is consistently well above the national average for all students • White British students from low income backgrounds are by far the largest of the main disadvantaged ethnic groups • In spite of these overall improvements, the attainment of Pakistani and Black Caribbean students remains below average	Ofsted 2013

Table 2.5: Overview of findings on the role of ethnicity in STEM

Ofsted (2013) commissioned and recently published a report on how there were still “unseen children” from disadvantaged backgrounds, which required addressing and that a student’s ethnic background (and factors such as material poverty) by itself should not be a “barrier to success”. During this report, their focus on raising the educational standards and the quality of teaching led them to conclude a key finding, that White British students of low-income families were the lowest performing group in England’s education system. Thus, students from the largest ethnic group in England who were eligible for Free School Meals (FSM) were underachieving, being below the national average in both English and mathematics.

2.2.3.3 Underrepresentation depending upon socio-economic background

Studies have shown how socio-economic status (SES) can act as a barrier to students studying STEM at higher education and, therefore, entering the STEM workforce (The Royal Society 2014; CaSe 2012). Hence, it has been suggested that students from a lower socio-economic background, especially if their attainment levels at GCSE were low, are less likely to study STEM subjects.

The Social Market Foundation (2013) supported this view as they found raising students' performance in GCSE science amongst those eligible for free school meals to the same as the rest of their cohort, would have increased the number of students studying A level science by an average of 3,000 to 4,000 each year, or 4% to 5% higher per year Broughton (2013). Table 2.6 lists studies that have focused on student underrepresentation in STEM depending on their socio-economic background.

Underrepresentation depending upon socio-economic background	
Key Findings	References
• Socio-economic background has a strong effect on an individual's likelihood of entering the scientific workforce • People with better educated parents and people from middle-income families were most likely to enter science • Individuals from lower socio-economic backgrounds who did enter the scientific workforce took longer to do so than those from higher socio-economic backgrounds	The Royal Society 2014
• There is underrepresentation of people from lower socio-economic groups amongst those applying for STEM degrees	Kumar, Randerson and Kiwana 2013
• Lower socio-economic status may still be a barrier to STEM education • Rise in the social diversity of young students (under 21) entering Higher Education as a whole as well as in STEM • Amongst undergraduate students, a better-than-average level of socio-economic status (SES) diversity was found in the biological and computer sciences	CaSe 2012

• However, in the physical, mathematical, engineering and technological sciences, degree courses showed significantly lower socio-economic diversity than the higher education average • The proportion of young students from lower socio-economic backgrounds and state schools enrolling in engineering and technology subjects was largely in line with the average across all subjects	
• If those on free school meals in England had done as well in GCSE science in recent years as the rest of their cohort, the number of students doing A level science in England would have been higher by an average of 3,000 to 4,000 each year, or 4% to 5% higher per year	Broughton 2013

Table 2.6: Overview of findings on the role of socio-economic status in STEM

Raising the education standard can support the attainment of young people through all levels and build the STEM workforce that is diverse, and which utilises skills and talent of those underrepresented in STEM; thus, addressing the challenge of employing qualified STEM graduates strategically (Race for Opportunity 2015).

2.3 Impact of the shortage of STEM professionals on the UK economy

The Roberts review, SET for Success (2002), found greater focus towards research and productivity standards was required in order to support the future of the UK's economic growth and performance level, leading the Government to produce the ten year "Science and Innovation Investment Framework 2004-2014". Whereas, the review led by Leitch (2006) gave importance towards developing key skills and concluded that this will unlock the potential of the workforce, who he considered to be a natural resource.

A review conducted by Lord Sainsbury (2007) provided a similar outlook, giving greater emphasis towards innovation to counter the rising pace of the economies of our competitors'. He expressed the need to progress further and "race to the top" as the potential challenges faced could be considerable. The Government's Plan for Growth (2011) report reinforced this view stating that the economy was "less competitive and less prepared to meet the challenges of the future" compared to other world leading countries (HM Treasury and BIS 2011). However, it highlighted that "the foundation of economic success," is heavily dependent on the standard of our education.

Furthermore, a recent report by the Government highlighted its plan for growth in science and innovation (2014) and indicated its strategy of further investing in people so that it can "attract, educate, train and retain" a workforce that is ready for the future challenges (HM Treasury and BIS 2014). To support this, in 2009 the Council for Industry and Higher Education (CIHE) predicted that: "jobs of the future will increasingly require people with the capabilities that a STEM qualification provides" (Hermann 2009). The Prime Minister David Cameron in 2013 expressed a similar view when he stated, "if we are going to succeed as a country then we need to train more scientists and more engineers" (Levanti n.d.).

In addition, the impact made on the economy from the engineering sector in 2014 has been outlined by the Engineering UK report (2015), which reported an estimated contribution of £455.6 billion (27.1%) of the UK's total £1,683 billion GDP (Kumar, Randerson and Johnson 2015).

The UK Businesses are recognised as the "engine of innovation, a generator of wealth and a driver of improved living standards" (Department for Innovation, Universities and Skills 2008). Their contribution has been crucial to the growth of the economy, such that businesses from the Engineering sector since 2013 have grown by 6.7% and produced a turnover of £1.17 trillion to the economy ((Kumar, Randerson and Johnson 2015). The CBI's annual Education and Skills surveys represent the voice of many businesses across the UK and provide a detailed overview of the problems facing businesses due to the relatively low number of people with STEM qualifications, especially in science and mathematics. Their eighth survey, *Inspiring Growth* (2015), collected data from over 300 organisations (that collectively employed more than 1.2 million people) highlighting the current and expected difficulties in recruiting people with STEM skills and knowledge. Their results showed that, during the next three years, 46% and 52% of businesses anticipate a rise in the lack of technicians and of experienced staff with STEM skills and knowledge respectively.

2.4 Reasons behind the shortage of STEM professionals

Many studies have identified a number of issues that cause the “disconnect” between the demand and supply of qualified STEM graduates and as a result impact on the shortage of STEM-skilled professionals (Roberts 2002; IET 2008; National Audit Office 2010). Along with the shortfall of women represented in STEM subjects at A level and in higher education, another major cause for concern has been students’, parents’ and teachers’ poor perception and lack of understanding about STEM careers and the opportunities brought by STEM qualifications (Holman and Finegold 2010). However, despite repeatedly discussing these barriers, the negative views and the lack of understanding of STEM careers remain.

2.4.1 The Image problem

Several studies suggest students’ perception and lack of understanding of STEM subjects and careers often leads many young people to be disconnected from STEM, feeling that it is not for them (IET 2008; Mellors-Bourne, Connor and Jackson 2011). A commonly developed opinion is that STEM subjects are too “difficult” and are studied only by those who are “clever” and most able (The Royal Society 2014a). Another misconception that has negatively impacted students’ attitude as well as their perception of STEM subjects and careers is that it is for boys and not for girls (Atkins 2013). STEM careers, especially in engineering, have been portrayed as a “male career”, leading many girls to question the relevance and their own ability to study STEM subjects further. As young people during adolescence start to form an identity, their view of STEM impacts on their subject choices (Zecharia et al. 2014). Key studies that have highlighted the impact made by the negative views of STEM as a barrier to studying STEM subject beyond post-compulsory education are listed in Table 2.7.

The Image problem	
Key Findings	Reference
• Image and opinions on science and technology careers are types of influences associated with STEM study or STEM career choices • Awareness about engineering as a profession is recognised as being poor • Relatively few people know what engineers actually do • There is confusion between the different types of engineers and the contribution that engineering makes to wealth and human/social wellbeing, especially amongst young people • Some recent research has found somewhat more positive views (reported in Engineering UK 2009)	Mellors-Bourne, Connor and Jackson 2011
• Seven in eight female engineers believed greater awareness was needed of what engineers do • Key perceptions that were highlighted by women engineers: Three-quarters believed engineering is still regarded as being a male career. Just over two-thirds thought engineering was believed by too many to involve fixing engines. Over half of the sample (55%) said they believed potential students are being put off by an idea that engineering is 'too difficult'. 43% said they believed engineers were thought to require physical strength	Atkins 2013
• Young people and parents often perceive science to be a hard subject, suitable for only the most able pupils, and that scientists are 'mostly white, male and middle-class', leading many young people to feel that it is not for them. Such an attitude is reinforced from an early age, with many children's books depicting scientists as fitting this stereotype	The Royal Society 2014a
• Girls have to be engaged earlier and across all education levels • The perception of digital and STEM jobs and subjects as male-orientated must be addressed	House of Lords Select Committee on Digital Skills 2015
• Lord Browne of Madingley, the former chief executive of BP, said the engineering profession was struggling to attract young people because they did not understand it	Moody 2015
• STEM subjects are seen as hard and unrewarding, with success in STEM being viewed as having connotations associated with being a nerd or a geek. These same image problems extend into perception of careers, with students not perceiving STEM subjects as a passport to lucrative and interesting jobs • The perception exists that anyone who enjoys or succeeds in STEM subjects is, or might be, a geek or nerd and the subject matter is not funky. Such images are frequently reinforced by the media, peers and parents who are the major influencers when deciding to opt for STEM subjects or a career, or not	IET 2008

• Over 80% of year 6-9 students see scientists as brainy • Views of science as male-dominated • More girly girls are less likely to express science aspirations • Only for clever girls	Archer 2014
• When it comes to choosing STEM at school, university or as a career, the literature is clear that there are three key factors. This applies to all students, regardless of gender: -The relevance of STEM = Is it for people like me? -Perceived ability = Do I feel confident? -Science capital = Can I see the pathways and possibilities?	Zecharia et al. 2014
• 70% of people around the world associate being a scientist with being a man • A strong popular perception among students and parents that STEM careers, particularly those in the physical sciences, are masculine	House of Commons Science and Technology Committee 2014
• The 'stick with science and mathematics' message is not only about subject choice, but it is also about persevering • Many young people find science and mathematics difficult and are tempted to give up trying long before they take public examinations • If the value of science and mathematics to future careers is better known, there will be incentives for younger students to persevere	Holman and Finegold 2010
• STEM has an image problem. Negative connotations surrounding STEM came straight to mind for the majority of people • STEM has a set of stereotypical concepts. It's perceived as too boring and dull, and the people opting for STEM are considered to be geeks or nerds • There is a gender-biased view perceiving STEM as a predominantly male field • Even the young people who are already engaged with STEM are self-conscious about being perceived as socially uncool or weird • People going into STEM are perceived as uncool and associated with a lack of social skills and boring social life	BIS 2014a

Table 2.7: The image problem

2.4.2 Parents as barriers

A longitudinal Economic and Social Research Council (ESRC) study led by Professor Louise Archer (2013) for an ASPIRE project at King's College London investigated the factors that develop science aspiration and career choices amongst many young people (age 10-14). When asking students if they aspired to be a scientist, the study found parents and family members played an important role, as a key factor associated with family members was science capital. They defined science capital as one who has "science related qualifications, understanding, knowledge (about science and 'how it works'), interest and social contacts (e.g. knowing someone who works in a science related job)". Hence, this meant those students with a higher science capital background were more likely to be influenced by their subject choices and have greater aspirations for a science related job. This study also gave importance to family members' attitudes to science as it suggested negative attitudes from them adversely affected students' attitude to science.

Whereas, other studies showed parents often lack impartiality and many do not encourage their sons and daughters equally to seek science further either as a subject or as profession (BIS 2014a; The Royal Society 2014a).

Overall, many parents along with students and teachers have a lack of understanding on the benefits of STEM qualifications and careers, and this has been a barrier for many young people persevering to STEM education and careers. Studies on the role of a parent in preventing students' subject choice and careers in STEM are listed in Table 2.8.

Parents as barriers	
Key Findings	Reference
• A poll for Tomorrow's Engineers Week found: (Engineering UK 2015): -12% of parents would like their son to become an engineer and only 2% said the same about their daughter - the lowest proportion for any job -16% would prefer their daughter to become a teacher, only 5% would like their son to	Kumar, Randerson and Johnson 2015
• Home support is a greater influence on achievement in physics than prior attainment • There is reinforcement on the importance not just of family support but specifically 'science capital' on student aspirations to pursue a science related career by the age of 14 • Those from families with higher science capital are more likely to aspire to and plan to participate in STEM study and careers while those who have lower science capital backgrounds and did not express STEM aspirations at age 10 are unlikely to develop them by the age of 14	Archer 2013

• A lack of this science capital has led many to be unaware of the diversity of post-16 routes and, therefore, to believe that post-16 science qualifications are "not relevant for me"	
• This lack of knowledge of the breadth of careers in science appears to be affecting science aspirations and participation rates. This issue is particularly acute for families with little 'science capital', and who are particularly likely to be from White and Black working-class backgrounds • More children and families would benefit from understanding that science and mathematics qualifications have a strong exchange value in the education and labour market and are not purely specialist routes leading to a narrow range of careers in science	Archer, Osborne and DeWitt 2012
• It was important to provide comprehensive careers information to young people and their families regarding the range of options available to physics graduates • Teachers felt that the parents of the student cohort had significant influence over the students' career aspirations and for this reason getting parents "on-side" was essential • Engaging parents and ensuring they were aware of the various well paid and high-profile careers available from physics and science worked extremely well	Institute of Physics 2014
• 15% of the pupils surveyed described advice from family and friends as being the most important factor in deciding on their future career	Davies and Cox 2014
• Attitudes of parents to STEM are a key factor influencing young people's future qualification and career choices • Cultural factors, parental aspiration and familiarity with STEM subjects, are thought to influence these attitudes	Finegold 2011
• The Royal Academy of Engineering noted that 'parents have a huge role in influencing the career choices and aspirations of their children. Mothers in particular wield significant power in directing their daughters down specific career paths'	WISE 2015

Table 2.8: Parents as barriers

2.4.3 Teachers as barriers

Many studies have established that high quality and inspirational teachers play a critical role in retaining student interest and enjoyment in STEM subjects. As they share their knowledge and expertise with young people, they are found to impact students' attitude to STEM qualifications and influence their subject and career choices (TLRP 2006; IET 2008; Holman and Finegold 2010; The Sutton Trust 2011). However, the current mathematics and science teaching workforce lacks quality and the quantity of specialist STEM teachers that are trained to a sufficient level to support the future supply of well-qualified STEM graduates and technicians (The Royal Society 2014a). Nevertheless, “bad teaching” can influence students’ experience and, therefore, negatively impact their desire to further study STEM subjects and career post-GCSE (Kumar, Randerson and Johnson 2015). A study by Ofsted (2013) found teachers’ expectations made a difference to how students from low socio-economic background performed on their GCSEs, therefore, giving great importance to the student-teacher relationship (Institute of Physics 2012).

Table 2.9 summarises previous studies that outline the impact of quality teaching on students’ views, attitude, experience and understanding of STEM subjects, including the gender differences that discourage the uptake of STEM subjects.

Teachers as barriers	
Key Findings	Reference
• There is a need for quality teaching for students to become and remain engaged in STEM • Good teaching contributes to young people enjoying STEM subjects • Strongest direct influence on positive attitude toward science is that of high quality, inspirational teaching • The science curriculum content is seen to be boring • Teaching is boring because it is often perceived as knowledge transmission of correct answers without time nor room for creativity, reflection or offering opinions	IET 2008
• One of the issues behind this shortfall of STEM professionals is a lack of young people studying STEM subjects at schools and colleges, which is in turn down to a dearth of properly trained specialist STEM teachers • One improvement we are certain works is to have more high quality, specialist teachers and the best way to achieve that is for the engineering community to realise that an engineer teaching physics in a school is a valuable commodity for both the country and for engineering • The one proven method of increasing the number and proportion of girls doing physics is to improve teaching. This is consistent with research, which indicates that girls are more sensitive than boys to bad teaching	Kumar, Randerson and Johnson 2015
• Sexism, such as differential expectations and encouragement for girls to continue with STEM. There is some evidence of “teachers	House of Commons

favouring boys and perceiving them to be better (and more naturally able) at science than girls, even where attainment data indicate otherwise” • We encourage the Government to work with the STEM community and schools to tackle gender stereotypes in education, particularly at primary level. In addition, we re-iterate the importance of engagement with STEM industry being part of teachers’ CPD	Science and Technology Committee 2014
• Part of the explanation for student attitudes toward school science may be a shortage of well-qualified science teachers capable of providing a positive experience. Moreover, many science teachers are required to teach sciences outside their own specialism. This undermines their confidence, leading them to offer a significantly more closed and less stimulating experience	TLRP 2006
• As well as young people themselves, and their parents, it is particularly important that careers advisers, teachers of STEM subjects and perhaps most important of all head teachers and school managers, understand the value of STEM qualifications in transforming young people’s life chances. Currently, in secondary schools and colleges, there are real disincentives that discourage students from choosing science and mathematics	Holman and Finegold 2010
• Teachers in the independent sector are more likely to have a stronger knowledge of the subject they are teaching. For instance, 76% of physics teachers in independent schools have a physics degree compared to 50% of physics teachers in state schools • Similarly, 70% of maths teachers in independent schools have a maths degree, compared to fewer than 50% of teachers in the state sector, such a gap also exists for modern languages, chemistry and biology	Broughton et al. 2014
• Where disadvantaged pupils study academic GCSEs, they achieve as well as other pupils when teachers hold the same high expectations for all • Uninspiring teaching was one reason pupils gave to inspectors to explain why they did not wish to continue studying science after GCSE. Another was not seeing the purpose of what they were studying, other than to collect examination grades • Timetables in a significant minority of the primary and secondary schools visited did not allow enough time for teaching science through regular, enquiry-based learning. This limited pupils’ opportunities to develop the practical skills necessary for future work in science, technology or engineering. This included restricting science to irregular ‘science days’ in primary schools, and limiting the teaching time for the three separate science GCSEs to the same amount as for a double science award in secondary schools	Ofsted 2013a
• The main influences on students’ attitudes to physics were found to be: -Self-concept (that is students’ sense of themselves in relation to the	Institute of Physics 2012

subject) -How students experience physics at school -Teacher student relationship • Gender stereotyping by both teachers and pupils needs to be actively challenged both in and out of lessons and across all subjects (see The gender equality duty and schools – guidance for public authorities in England EOC 2007) • In science, the attitude that "physics is for boys" should be discouraged among students and teachers	
• A significant positive relationship between pupils' interest in physics and how often teachers report that they link physics with everyday life • A significant negative relationship between pupils' interest in physics and how often teachers encouraged dialogue between pupils and themselves • A very strong positive correlation between how often teachers claimed to link their physics lessons with everyday life, and how often pupils felt that this was happening. This is an important and meaningful finding as it seems to show that pupils clearly picked up on what teachers were doing in this area	Rietdijk, Grace and Garrett 2011
• Participating students highlight the impact on them of restricted involvement in practical/hands-on sessions in classroom science. The science curriculum is heavily content loaded which reduces teachers' opportunities for engaging students in practical sessions • In contrast, the Design and Technology curriculum places priority on hands-on activity with much less theoretical input • As physics and design and technology have much in common through maths and shared concepts it would be of benefit to students if school departments collaborated to integrate subject content through, for example, project work which combines concepts and practices from both areas	Bevins, Brodie and Brodie n.d.

Table 2.9: Teachers as barriers

2.4.4 Lack of careers advice

Students' lack of awareness of the diverse range of STEM careers and the quality of careers advice given to young people is a major cause for concern. Studies have emphasised the need to start providing careers information from an early age (Holman and Finegold 2010; Davies and Cox 2014). Although most students make their first informal decision on their future career path by the age of 14, some children during primary education start to build an aspiration of who they would like to be when they are older (Holman and Finegold 2010; The Royal Society 2014a). Thus, forming general knowledge and awareness is critical for younger pupils as it allows them to become aware and later support their subjects and career choices with an informed decision.

A study led by BIS (2011) found almost a third (30%) of STEM undergraduate students would have preferred additional careers support, both before and during their university course (Mellors-Bourne, Connor and Jackson 2011). Therefore, building students' awareness and understanding of STEM careers and improving the quality of careers advice given during all education sectors, primary, secondary, further and higher education is fundamentally important.

In some studies businesses have expressed frustration towards the quality of careers advice given to young people. A study conducted by CBI (2015) found nearly four out of five businesses (77%) across the UK were unsatisfied by the quality of careers advice provided and felt this impacted the likelihood of a student making an informed future decision. The lack of high quality careers advice given to young students has limited student's vision and understanding of the various routes that open through STEM qualifications, making students unaware of the rewarding career choices gained through further studying STEM subjects beyond GCSE (Sainsbury 2007).

An overview of key findings that address the need for quality careers advice is presented in Table 2.10.

Lack of careers advice	
Key Findings	Reference
• All young people are entitled to receive good guidance on careers from an early age, and in particular, on the opportunities that studying STEM subjects can bring • This is especially important when young people are benefiting from a breadth of education to age 18 • Yet only a 'minority' of schools have routinely worked with employers to support teaching and learning, although almost all work with them to support work experience	The Royal Society 2014a
• For better informed choice, there is abundant evidence of the need to start young – much younger than the careers advisory service is currently configured towards • Of course, high quality careers advice is needed right through to adulthood, but the evidence is clear that decisions about directions of travel are often made at a very early age • Children begin in primary school to form a picture of what their future lives will be like, leading to the first of a series of formal decisions made by the age of 14 • So it is critically important that the work of building general awareness of STEM careers begins in primary schools and at Key Stage 3 when students make subject and qualifications decisions, so that they do so in the light of good information about their long-term value	Holman and Finegold 2010
• University students claim to have benefited from additional career support and that it would have most certainly impacted their career and educational choices • 30% of STEM final year students reported that they would have benefited from more career support (both before and while they were at university) and were less likely to have a definite career in mind in their final year (30% and 21% respectively) compared to 38% of other final year students	Mellors-Bourne, Connor and Jackson 2011
• There is a major need to improve the level of careers advice provided to young people so that they are aware of the exciting and rewarding opportunities open to those with science and technology qualifications • Careers advice should be built into the curriculum for pupils and into Continuing Professional Development (CPD) for teachers	Sainsbury 2007
• A need for awareness raising of fundamental understanding was identified in several areas – most applying equally to both genders: - 77% engineering women surveyed believed greater awareness of the wide range of careers employing engineering graduates was required - Almost two-thirds of women engineers believed that careers advice about engineering was weak	Atkins 2013

• Careers education was generally weak in Key Stage 3. This made informed choices of courses and careers difficult • In particular, the girls spoken to had only limited knowledge and understanding of how their choices influenced their future pay and progression	Ofsted 2011
• Pupils as young as 12 are engaged in thinking seriously about their careers, but findings show that they want more help, more work experience and more information about local job opportunities, including visits from employers and visits to their sites • This help is necessary especially as the lack of interest in post-GCSE STEM courses and vocational education among girls, for example, is a cause for concern given that skills shortages in these sectors are looming • Pupils had insufficient knowledge about which careers did and did not have science qualifications as prerequisites • There is great importance of educating young people early on about both careers and the educational choices they will need to make in order to realise their ambitions: it is an issue for pre-GCSE ages, not just after the age of 16	Davies and Cox 2014
• Nearly four out of five businesses (77%) across the UK feel the quality of careers advice young people receive is not good enough to help them make informed decisions about future career options. Only 7% consider the quality of current careers advice to be adequate, producing a negative balance of -70% • More than one in four respondents (27%) also want to see an improvement in the quality of careers advice running alongside higher levels of business engagement with young people aged 11 to 14 • Young people need better advice and guidance on the varied routes open to them and the qualifications they will require to pursue them	CBI 2015
• Business believes that careers advice for young people should be based on the following five principles: 1. Careers information, advice and guidance should be an integral part of the school curriculum from year 7 onwards 2. High quality information on the careers destinations different education and training choices should be made available to students 3. This information needs to be supported by unbiased and personalised advice and guidance for all young people, delivered by properly-trained careers advisers and teachers 4. Involving employers is essential to supporting young people to make informed decisions about their future career options 5. There should be a seamless transition between pre-19 and post-19 careers services	CBI 2010
• Careers education does not normally have high status in schools and the relationship between careers provision and individual subject departments are often weak or non-existent	Finegold 2011

• Schools that have set up STEM working groups involving careers staff, STEM teachers and senior leaders are able to offer a better STEM learning experience for pupils • There is a risk that STEM careers support in schools may be scaled down as a consequence of the Government's Education Bill in which schools will have a statutory duty to ensure that pupils are provided with careers guidance, and which gives schools flexibility over how it is provided • Links between what young people learn in STEM subject lessons and the implications for career choice must be made explicit since there is an incorrect assumption that pupils forge links between curricular subject knowledge and the jobs available to them • Pupils also need to know that for some STEM careers, studying three separate subjects rather than triple science is desirable, and in some cases essential	

Table 2.10: Lack of careers advice

Therefore, to address the shortage of STEM professionals requires improving the attitudes of teachers, young people and their parents to STEM (Holman and Finegold 2010). Limited viewpoints combined with lack of knowledge of STEM careers, together with the quality of schools science facilities and availability of triple science qualifications on the school curriculum are all barriers deterring young students considering their options to further study STEM qualifications. All these factors impact on the supply of qualified STEM graduates needed to meet the future demand of STEM-skilled workers (National Audit Office 2010).

2.5 Strategies to enhance the number of STEM professionals

Realising the importance of high quality education and skills, the Government has introduced fundamental measures that are anticipated to have a long-term impact on students' mathematical, scientific, digital and creative knowledge, understanding and skills. Strategies such as changes in the curriculum, improvements to the quality of alternative qualifications and the uptake of trained specialist teachers, as well as reinforcing the link between businesses with schools and universities, have been given great priority to support the vision of qualified STEM graduates and professionals.

2.5.1 Changes in the curriculum

Since the Smith report (2004), the Government has made many key changes to the curriculum, qualification and pedagogy in the provision of post-14 mathematics education. From September 2015, the reformed GCSEs in English and Mathematics will be taught, following a new grading system (9 to 1 with 9 being the highest grade) in 2017. The curriculum for GCSE Mathematics has also changed and is now more "challenging" with a greater focus on students building problem solving skills, fluency and mathematical reasoning (OCR 2013). As well as strengthening the GCSEs, A level Mathematics has shifted from modular to linear assessments and from September 2017 a new AS and A level Mathematics and Further Mathematics qualification will be introduced (AQA 2016).

In addition, following a key recommendation by ACME (2011), the Government from September 2017 introduces a new core mathematics qualification (equivalent to a level 3 qualification) that allows students to study the subject from age 16 to 18. This has been designed so that students who do not opt to study A level Mathematics still have the opportunity to continue building strong key numeracy and reasoning skills required by many high valued jobs. Furthermore, those that do not achieve at least a C in GCSE Mathematics (equivalent to grade 3 or lower) are required to gain this qualification during their post-16 education, ensuring all young people by the age of 18 are sufficiently equipped with their mathematical ability (this applies to GCSE English as well). The reforms signify the importance of quality mathematics education and clearly demonstrate the efforts made by the Government to produce world-class individuals with a strong mathematical background that is needed for a range of STEM and non-STEM jobs.

The Government has also implemented key changes to the GCSE science curriculum, which will be taught from September 2016. This is designed rigorously so that young people are assessed on their practical skills as well as mathematical ability at an appropriate level of difficulty (Ofqual 2015).

In 2014 a new computer science curriculum was introduced which applies from primary level upwards. This has a greater emphasis on learning how to code and understanding how a computer system works rather than simply how they are used (Computing at School 2012). However, although this has been viewed as a major step towards giving the UK a competitive edge, the Select Committee on Digital Skills (2015) has outlined the difficulties faced by many teachers delivering the new computer science curriculum.

The new national curriculum for design and technology will also be introduced from September 2017 to further develop students' practical and creativity skills that solve real and relevant problems and allows them to apply their skills to create products for a wide range of users (DfE 2013).

2.5.2 Vocational education

Addressing the alternative routes to employment and higher education or training was a key priority set by the Government (BIS 2014). A vocational route allows young people aged 16 to 19 to build technical skills and gain specialist skills and knowledge and, therefore can play an important role in overcoming the shortfall of the STEM-skilled workforce. Hence, the provision of reformed vocational education is being implemented, ensuring high quality standard qualifications are developed that are rigorous and responsive to technological changes (Perkins 2013).

A critical part of this process has been to develop qualifications that meet employers' needs and are viewed as desirable as the traditional A level route, for employment or progression in higher education. To support this, in 2009 the CIHE reported how there were organisations that valued the apprenticeship route, alongside the graduate or postgraduate intakes. However, it was recommended that there was further research conducted to investigate the potential of those from alternatives routes coming into employment (Connor and Brown 2009).

Nevertheless, a review by the National Apprenticeship service (2015) stated findings from an Independent Communications and Marketing (ICM) Research study. They found employers valued qualified higher apprentices as they felt they were 25% more employable than those that took a different route into work (Turner 2015).

A review commissioned by BIS in 2014 addressed the importance of increasing the number of young people taking technical apprenticeships as they were valued by employers in STEM sectors. They further expressed how many employers through the use of the STEM ambassador scheme enaged in outreach to promote STEM careers and opportunities. They viewed this as a "partial solution" to effectively target the disadvantage groups (e.g. women) to take up STEM careers though BIS found that schools were not always keen to engage with employers. This could potentially be due to exam pressures and the outreach activities not having a direct link to the national curriculum (McCaig et al. 2014).

Improving the quality of apprenticeships with the involvement of businesses has been part of the Government's agenda with a plan for the creation of 3 million apprenticeships by 2020 (BIS and Boles 2015). In a related move, school performance tables will no longer take account of low value vocational qualifications. This is to discourage schools and teachers influencing 14-19 year olds towards qualifications that have little vocational potential.

2.5.3 Uptake of specialist teachers

The Government has introduced a range of incentives in order to attract high quality specialist trained teachers, to support the uptake of the number of students inspired and encouraged, especially girls and young people from a low socio-economic background, to further study STEM subject's post-GCSE. A key approach has been through a scheme awarded by many professional institutions (The Institute of Physics, The Institute of Mathematics and its Applications, The Royal Society of Chemistry, and BCS, The Chartered Institute for IT), which provides a tax-free bursary or a scholarship of up to £25,000 to mathematics, physics, chemistry and computer science graduates for their initial teacher training year. Other initiatives have also been introduced to increase the quality and quantity of the teacher workforce.

Since the Prime Minister, David Cameron, announced “maths and science must be the top priority in our schools,” many schemes have been launched to support and retrain non-specialist teachers and attract more graduates, postgraduates, researchers and career changers to become specialised mathematics and science teachers. Over the next five years, the new programmes are projected to retrain 15,000 existing teachers, as well as recruit an additional 2,500 specialist teachers (Prime Minister's Office et al. 2014).

Furthermore, the Mathematics and Physics Chair Programme, introduced by the Government, supports doctoral researchers to be recruited as enthused trained teachers and make a difference, specifically at non-selective state schools (DfE and Gibb 2015). In addition, a scheme run by the British Computer Society and funded by the Government aims to recruit 400 master teachers in computer science to support the teaching training in other schools and the development of resources that teachers can then use in classrooms (Coughlan 2015). As there is also a growing need to address the skills gap of design and technology teachers, a structured programme that links schools with industry, focuses on enhancing knowledge and technical skills of design and technology teachers has been launched (Skills Gap 2013).

Establishing the importance of highly trained specialist teachers, the Government has introduced a range of approaches to retrain and recruit new specialist mathematics and science teachers over the next Parliament. Furthermore, mathematics and science teachers are able to gain support with their professional development from the National Centre for Excellence in Teaching Mathematics and the Science Learning Centres (National Audit Office 2010). Therefore, by addressing a long-term change, these strategies can enhance the uptake of young people with a stronger STEM education background, required for studying STEM at higher education and career.

2.5.4 Employer engagement

The Roberts Review (2002) addressed the difficulties faced by employers in recruiting highly skilled scientists and engineers and said that action by employers was required if the future supply of the STEM workforce was to be successfully developed. It stated that “employers can exert real influence,” implying their role in raising the supply of STEM professionals is fundamental. Thus, employer engagement in education (at all levels) was identified as a key strategy to help overcome this challenge as it brings “employers/employee volunteers into contact with learners to enrich learning and support positive progression” (Mann and Oldknow 2012). Therefore, through various types of schemes (including work experience, careers advice, and workplace visits) this approach provides young people with supplementary and complementary support to achieve learning outcomes not usually developed during school.

The Secretary of State for Education, Nicky Morgan (Department of Education 2014), outlined the significance of deeper collaboration between businesses and schools as a key approach to addressing the skills shortage of STEM graduates. She emphasised the need to build strong links between them as an effective way to allow young people to value STEM qualifications and the opportunities that come with them. Furthermore, strengthening the relationship between businesses and universities has also been outlined as a key approach; as this ensures the quality and skills developed in a STEM graduate positively address business needs (CBI 2015).

A report commissioned by Futurelab (2012), outlined three routes through which the delivery of employer engagement related to STEM education activities in England can occur; national intermediary organisations (e.g. The Smallpiece Trust and STEMNET), local intermediary organisations (also known as Education Business Partnership Organisations (EBPOs)) and direct relationships between schools and employers. The key purpose of all employer engagement activities has been “to improve awareness and interest in, STEM careers and progression pathways, serving to increase pupil take up of STEM study within the education system; and to improve pupil achievement in STEM subjects through enrichment and enhancement activities” (Mann and Oldknow 2012).

Therefore, through a holistic approach, the Government has pledged to increase the number of high quality STEM professionals, as the current and planned changes are long-term approaches to help address the supply of skilled and qualified STEM graduates and professionals.

2.6 STEM outreach

A key strategy that addresses the shortage of STEM professionals is an “initiative designed to inform or invite students into STEM pathways” through STEM outreach (Packard 2011). It is an approach that is welcomed by the Government, professional institutions, voluntary organisations and Higher Education Institutions as it supports a common mission; “to inspire and equip children and young people to become the scientists of tomorrow” (Wynarczyk and Hale 2009).

Through a wide range of events and projects, young people can engage with STEM enhancement and enrichment activities, supporting their understanding of and interest in STEM subjects and careers (Finegold 2011; Parliamentary Office of Science and Technology 2011; Mann and Oldknow 2012; Perkins 2013).

This approach was found useful by the Wellcome Trust (2014), especially for pupils from disadvantaged backgrounds that are disengaged from formal (school-based) learning (Atkinson, Siddall and Mason 2014). Outreach supports and contributes to the goal of increasing students’ awareness of the opportunities in STEM and provides students with an experience that is different and is often integral to their usual classroom learning environment and thus seeks to further enhance the learning of key concepts of STEM through a range of ways. BIS in 2012 released a policy paper, highlighting initiatives that were funded as part of the Government plan to increase “public understanding of science and engineering”. Their primary focus of funding these initiatives was to raise general awareness of STEM and its relevance, as well as inspire young people to study STEM subjects and increase progression to STEM careers (BIS and Clark 2012). Nevertheless, the STEM programme report conveyed their mission, which was “to capture the imagination of young people who will become the scientists, technologists, engineers and mathematicians of the future, and help them reach their full potential” (Rammell, Adonis and Sainsbury 2006). This was believed to be attainable “through the delivery of STEM support in the most effective way to every school, college, learning provider and learner”. Thus, through informal education, the national STEM learning agenda is reinforced as it can impact and support students’ attitude, preconceived ideas, behaviour, understanding, knowledge and confidence in their ability to "do" STEM subjects (Parliamentary Office of Science and Technology 2011).

2.6.1 Types of STEM activities

Engineering UK (2015) outlined the BG Group's STEM Education Learning reports' (2013) recommendation of six key elements to take into account when designing STEM education activities, which were:

- "Stimulating and practical learning that is relevant to work, life and local conditions
- Interactive scientific enquiry and problem solving
- An enriched curriculum, with informal learning and extracurricular activities
- Confidence building in STEM, especially for disadvantaged groups
- Information and advice on STEM study, qualifications and careers
- Continuing professional development for STEM teachers"

BG Group promotes delivering outreach activities that align with the above goals to contribute towards making a positive impact on young people's engagement in STEM subjects. As a result, all indicate an ultimate goal of improving pupils' achievement and increasing the uptake of the supply of qualified STEM graduates and technicians for the STEM workforce.

The STEM Mapping Review (2004) identified over 470 STEM initiatives, initiated the STEM Cross-Cutting Programme which categorised the types of activities to three broad strands (Rammell, Adonis and Sainsbury 2006):

- "Teacher recruitment and retention
- Teacher professional development
- Enhancement activities for learners, including areas such as;
  - Careers advice
  - Extra-curricular activities such as clubs, booster classes etc.
  - Links with employers and work experience

- Campaigns, gender and ethnic minority focused activities
- Direct bursaries and inducements in shortage subject areas”

Therefore, supporting the key purpose of improving learning and engagement of STEM subjects and careers, the outreach activities represent pupil-based and teacher-based interventions (National Audit Office 2010).

However, the Good Timing report (Finegold 2011) expressed how these interventions focused less on “career learning” and instead described them rather as a way to generate interest in the subjects. The statutory guidance from the Department for Education (2014) outlined the schools’ responsibility towards following good practice to provide careers advice and inspiration to students in shaping their aspirations beyond education. A strong focus on interaction with employers, mentors and coaches has also been highlighted so that students can experience support towards making informed career decisions with quality and clarity. Therefore, viewing this as an employer-based intervention is another form of outreach activity (Mann and Oldknow 2012), as this seeks to “inspire pupils with a sense of what they can achieve and help them understand how to make this a reality” (DfE 2014).

Table 2.11 summarises a list of titles of STEM outreach programmes that are led by a range of providers, including professional institutions and voluntary organisations to support the long-term goal of increasing the uptake of STEM-skilled professionals.

Examples of STEM outreach initiatives	*Reference*
Your Life is an industry-led and Government-supported campaign, which aims to show the dynamic career opportunities unlocked by studying science and mathematics, and thereby drive uptake of mathematics and physics at A Level or equivalent	http://yourlife.org.uk/yl-about-us/
The Computer Clubs for Girls, an out-of-school club that provides a range of tailored e-learning activities for girls aged 10-14	Wynarczyk and Hale 2009
The Royal Academy of Engineering’s STEPS at Work initiative: enables teachers to spend a day at a local engineering firm, seeing for themselves industry in action	Perkins 2013
Engineering UK delivers The Big Bang Fair, The Big Bang Near Me Fairs, and Tomorrow’s Engineers	Kumar, Randerson and

	Johnson 2015
The Engineering Development Trust (EDT) runs a range of programmes aimed at supporting talented young people, aged 11-21	Mann and Oldknow 2012
The Smallpeice Trust promotes “engineering, manufacturing, enterprise and technology in all its branches as a career to young people”	Mann and Oldknow 2012
STEMNET (the Science, Technology, Engineering and Mathematics Network) raises the awareness of the importance of STEM subjects and interest in STEM careers	Mann and Oldknow 2012
To engage the public in science and engineering the Government - hold the British Science Festival and the National Science and Engineering Week, events that promote science and raise the public’s awareness of science issues	BIS and Clark 2012

Table 2.11: List of STEM outreach programmes

A database that can ease the search of STEM outreach activities is STEM Directories and through this various schemes involving a wide range of activities (such as challenges, competitions, ambassador programmes, workshops and web resources) can be found to support schools and teachers with their search for appropriate initiatives for their pupils (http://www.stemdirectories.org.uk/).

2.6.2 Recent government funded STEM outreach initiatives

The Higher Education Funding Council for England (HEFCE) funded four STEM outreach projects; More Maths Grads (2007-10), Chemistry for Our Future (2007-09), Stimulating Physics (2007-09) and the London Engineering Project (2007-09). These pilot projects were led by professional bodies each representing a STEM discipline; MSOR Network on behalf of the Mathematical Societies, the Royal Society of Chemistry, the Institute of Physics, and the Royal Academy of Engineering respectively. They were created to support widening participation within universities and to increase the intake of students studying STEM related degrees at Higher Education Institutions.

During this project, target audiences (for example students, teachers and parents) were considered and useful and relevant resources were designed. Additionally, through these projects, greater awareness and understanding of career opportunities related to STEM were made. Furthermore, key impacts from sigma were spawned as they successfully supported the increase in the number of Higher Education Institutions providing some form of maths support which in 2013 was 85% of those surveyed. This was highly valuable, as mathematics has been identified as a key barrier to student attainment on STEM courses. Although these projects overall supported widening participation and enhanced the number of student taking up STEM courses, they were pilot led projects with limited time and resources. The length of these projects was fairly short (3 years) and thus were unable to conduct a longitudinal study and thoroughly investigate the impact made towards the targeted groups. Further the projects were carried out in certain regions and so making it difficult to capture a detailed understanding of the successes and shortcomings of these projects on a national scale (Hughes et al. 2013; Gove 2013).

Nevertheless, the success from all four projects led to the three-year initiative, the National Higher Education STEM Programme (2009-12) and this was funded by the Higher Education Funding Councils for England and Wales (HEFCE and HEFCW). The key purpose for this project was to widen participation on a national level and actively continue the vision of increasing the number of students studying STEM subjects at post-16 and beyond and enhance their skills required in a STEM workforce (Grove 2013).

2.6.3 Stakeholders in STEM outreach

Many professional and voluntary organisations and universities support the delivery of outreach activities. Their engagement with schools/colleges and young people contributes to the impact made to the learning providers (teachers) and learners (students) such that through STEM outreach interventions, they can provide teacher CPD events and student enhancement and enrichment activities (DfES 2004).

The National Higher Education (HE) STEM Programme (2010) produced a guide that identified delivery and purpose of a range of activities, which were presented and categorised into five strands of outreach activities:

- “University-led outreach activities
- School-university interactions
- Engaging employers in outreach and curriculum enhancement
- The school-university transition
- Targeting underrepresented groups of learners”

Thus, the stakeholders in STEM consist of the providers of outreach; professional institutions, voluntary organisations and universities who seek to convey the message of the shortage of STEM-skilled graduates and employees through direct or indirect interactions with the learning providers (teachers) and learners (students). Employers from STEM related industries are often part of this progression as their involvement brings valuable knowledge and expertise that is essential towards making a difference to the participating students and teachers in their learning and understanding of STEM subjects and careers.

A report by ASPIRE highlighted the importance of these roles stating “it is not enough to seek to change only young people’s attitudes and perceptions” (Archer 2013). STEM industries, employers, professional organisations and universities all have a part to play in working towards more equitable cultures and patterns of participation and representation within their own organisations.

Therefore, through engagement with learners and learning providers, key concepts of STEM subjects are taught and understood, highlighting the combination of these relationships as critical to delivering effective STEM outreach activities (National HE STEM Programme 2010).

2.6.4 Impact of STEM outreach

The Department of Education and Skills in 2004 published the STEM Mapping Review, which provided a detailed report addressing the impact of over 470 STEM initiatives. It investigated whether these "teaching and learning initiatives" were fit for purpose in reinforcing the agenda of increasing the uptake of STEM subjects and careers. The key message emerging from this review in relation to impact and evaluation of STEM outreach was that more work is needed to improve its efficacy. The review found a lack of coherence and coordination in the plethora of STEM initiatives/programmes which was a cause for concern. A key finding was the "lack of readily available evaluation to make an assessment on the impact for most of the initiatives". Another key observation was that the purpose of many STEM activities was similar and so the need for them was questioned. This led to the introduction of a cross-cutting programme in STEM (DfES 2004), which further supported a greater understanding on the impact and effectiveness of its funding strategy in:

- The flow of qualified people into the STEM workforce; and
- STEM literacy in the population

A review by the National Audit Office (2010) also examined Government funded initiatives. Through multiple regression analysis, it investigated the impact of students' take up and achievement in mathematics and science GCSE and A level and its association between students attending particular STEM initiatives (as well as the variable school specialist in STEM). Although their findings suggest interventions such as STEMNET ambassador activities for students and training days in National Science Learning Centre for teachers significantly improved the percentage of students achieving grades A*-C in GCSE sciences, it suggested other factors are likely to have contributed to students results too. However, a key observation was that there are still schools that do not have access to student and teacher based interventions depending on their region. Many studies have investigated the impact of student, teacher and employer involvement in outreach activities and how they have impacted understanding and awareness of STEM subjects and careers (National Audit Office 2010; Mann and

Oldknow 2012; Archer 2013; Macdonald 2014). A summary of some of the key projects that highlight the effectiveness and impact of STEM outreach is presented in Table 2.12.

Key findings	References
• They found teachers and parents perceptions can be improved through The Big Bang Fair • As a result of attending the fair, they were more likely to recommend a career in engineering to an accompanying young person	Kumar, Randerson and Johnson 2015
• Participation by teachers in Learning Centre programmes is associated with improved teaching and learning, and higher take up and achievement in science at their schools, but take up by teachers varies between areas	National Audit Office 2010
• Teacher-based interventions successfully broadened students' views of where science can lead	Archer 2013
• Employer contact statistically increases a young person's experience in school (between the ages of 14 and 19), their confidence (at 19-24) in progression towards ultimate career goals, the likelihood of whether (at 19-24) they are NEET (Not in Education, Employment or Training) or non-NEET	Mann 2014
• There is positive impact of employers' involvement with students' education experience (these include preparedness for work, developing job and work skills, improving work-based competencies, attitudes and behaviours, enhanced employability and higher initial wage rates	DCSF 2008a
• Importance of employer engagement with pupils • In relation to Key Stage 4 pupils, teachers felt the greatest impact can be expected among middle and lower level achievers, as high achievers are commonly highly motivated already • In relation to Key Stage 5 students, teachers reported that young people gain both in terms of enhanced motivation to achieve, but also through improved contextualisation of learning	Kumar, Randerson and Johnson 2015

Table 2.12: Positive impact from involvement in STEM outreach activities

The BG Group's STEM Education Learning report (2013) reflected and shared its learning points to maximise the impact of design and delivery of STEM outreach activities, which include:

- “Prior to project delivery, sufficient time needs to be factored in for relationship building and engaging schools
- Interactive, contextualised and practical activities are particularly engaging for young people although there needs to be an increasing emphasis on theory as students get older
- Activities involving problem solving, investigations, teamwork and giving presentations can allow students to develop transferable and employability skills as young pupils may have less time to focus on this in school
- There needs to be a balance between fun and engaging activities and activities which have clear learning outcomes and which will develop knowledge, understanding, skills and confidence
- Drawing on STEM professionals and role models helps to place activities within the local context and raise awareness of, and enthusiasm for, STEM subjects and careers however, the volunteers need to be properly briefed to ensure their input is pitched at the right level
- Projects benefit from building in an element of teacher professional development even where the main target group is students – actively engaging teachers in activities and modelling delivery can build their capacity to deliver and sustain activities in school
- The ‘Train the Trainer’ model of professional development can be effective in cascading effective practice and resources to large numbers of teachers where the trainers are effectively supported and have the relevant experience, credibility and access to teachers
- To achieve a significant impact on students, activities need to be sustained over time and incrementally built on prior learning”

BG Group outlined these strategies as its “success factors” to planning and delivering impactful outreach activities for students and teachers.

2.7 Areas of improvement in STEM outreach practices for maximum impact

Several studies have identified areas of improvement in the provision of STEM outreach to effectively support the goal and vision of increasing the future supply of qualified STEM professionals (DfES 2004; Rammell, Adonis and Sainsbury 2006; Moore, Sanders and Higham 2013). Table 2.13 lists key findings that address this issue.

Key findings	References
• One-off interventions, competitions, role models, master class events and career talk events are not always effective approaches to STEM outreach	Macdonald 2014
• STEM outreach should be as accessible and engaging for disadvantaged groups as they are for those families from better-off backgrounds who already make extensive use of such activities	Atkinson, Siddall and Mason 2014
• Many STEM outreach activities address the wrong message of 'science = scientist' than rather emphasise that 'science keeps your options open' • Traditional outreach, involving role models and one-off events, are highly unlikely to change anyone's choices	Archer 2013
• Depending on the school, STEM clubs either target the more academically able or encourage anyone who is interested	Hutchinson 2013
• The BIS Science and Society programme (2013) presented key messages that few include targeting new audiences and engaging with people where they naturally congregate, rather than expecting them to come to you	BIS and Clark 2012
• There is a lack of coordination of all programmes and initiatives • There is a need to adopt a more holistic approach (an approach which looks at the whole/totality/the bigger picture and is a comprehensive approach) in order to bring coherence and make more of an impact	DfES 2004
• Lack of coordination and joining-up between many providers of professional development and enhancement activities • There is a need to achieve more coherent delivery, but without sacrificing diversity of choice	Rammell, Adonis and Sainsbury 2006
• Very little is known about STEM organisations' contribution and real impact on increasing the take up of science subjects • There remains a lack of overall coordination between the organisations about their STEM education activities • It is difficult to determine how the organisations approach schools, teachers and pupils, or whether they rely solely on potential participants to visit their website and find out for themselves • It is not clear how STEM initiatives are linked to the widening participation agenda	Wynarczyk and Hale 2009

Table 2.13: Overview of areas of improvement in STEM outreach practices for maximum impact

The findings from previous research express the need to “target new audiences”: findings suggest some activities reach “only small groups of enthusiasts”; an activity was only likely “to appeal to a very small percentage of the class”; certain activities can reinforce that “STEM is not for them” particularly if an event is only open to selected pupils (BIS and Clark 2012; Macdonald 2014).

2.8 Improvement required in the delivery of STEM outreach activities

Taking the above into account, this study investigates improving the delivery of STEM outreach activities through collaborating the views of the receiver (students), facilitator (teacher) and provider (professional institutions, voluntary organisations and Higher Education Institutions) involved in STEM outreach. Therefore, a detailed and comprehensive understanding of the facilitator and provider’s wealth of knowledge and experience with coordinating, delivering and evaluating STEM outreach as well as the impact of participating in the activities from the learners’ point of view is required.

In order to adequately investigate and understand the impact of the delivery of STEM outreach, an overview of key areas of improvement involving students, teachers and STEM outreach practitioners is presented in Table 2.14.

Areas of Improvement	Key Findings	References
Student’s perception and understanding of STEM subjects	• Biology is preferred to physics or chemistry as it is less complex • Science has not opened their eyes to new and exciting jobs • Little recognition that a science qualification may be as valuable as a generic qualification • Interest in their chosen subject area is a key motivator for pursuing a STEM degree • Need to increase awareness of routes into STEM from an early age, along with career prospects • “Scientists are brainy” and science careers are “not for me”	Bevins, Brodie and Brodie n.d., Jenkins and Pell 2006, Adecco 2015 and Macdonald 2014
Student’s aspiration and awareness on STEM careers	• Lack of knowledge and understanding of SET careers • Unaware of routes into STEM professions • Views on careers are often limited	Bevins, Brodie and Brodie n.d., Adecco 2015, Archer 2013

The impact of STEM outreach on student's choices of subjects and degree programmes	• Activities can reinforce the idea amongst those not selected that STEM is for the elite and not open to others • Untrained speakers risk discouraging prospective engineers rather than to incite the intended excitement and interest • Lack of parental backing • STEM activities have not been uniform across STEM subjects	Macdonald 2014 and Adecco 2015
School/College teacher's understanding and views on STEM outreach	• Students would like teachers to be more involved in STEM outreach events so that they can give them up-to-date careers advice • Lack of knowledge and awareness of STEM careers	Bevins, Brodie and Brodie n.d. and Atkins 2013
Outreach practitioner's awareness and understanding on the impact of STEM outreach activities on students	• A poorly trained/unsuitable scientist can actually have a negative impact on students • It can be hard to set an appropriate level for young children - I personally find it easier to explain to adults • Generally, they will not be understood unless they "dumb down" the content to an unacceptable level • Audience is not always appreciative of the outreach	Thorley 2014
Strategies of evaluation of STEM outreach activities	• There is a need to achieve more coherent delivery, but without sacrificing diversity of choice • Very little is known about their real impact on increasing the take up of science subjects • Limited studies, evidence and evaluation of STEM initiatives	Rammell, Adonis and Sainsbury 2006, Wynarczyk and Hale 2009

Table 2.14: Overview of areas of improvement in the delivery and impact of STEM outreach activities

2.9 Summary

This chapter included a comprehensive literature review on the impact of the shortage of STEM professionals and discusses in detail the reasons behind the shortfall and the key strategies that are implemented to enhance the number of well-qualified STEM professionals. An in-depth review of STEM outreach was conducted together with a summary of previous research into the impact of outreach activities on students' understanding of STEM subjects and careers. Recommendations for improvements in STEM outreach based on previous research provide the foundation for this new research and help to identify gaps in current knowledge.

Chapter 3

Key Stakeholders, Research Questions and Methodology

3.1 Introduction

This chapter details information on STEM practitioners, teachers and students and discusses the relationship between them. In order to understand students' key decision points, their education journey has been outlined, followed by an illustration of students' key influences towards a STEM degree and careers. In addition, alongside the research questions, the methodological approach and the development of a mixed methods research design, which utilises qualitative and quantitative data, has been presented. Following this, a thorough description of the sampling techniques and analysis used to conduct this research is highlighted and details of the development of the qualitative and quantitative tools used to collect the data are presented. Finally, careful consideration is given to the limitations and ethical issues related to this study.

3.2 STEM outreach model

STEM outreach practitioners seek to enhance and enrich students' learning experience and expose them to areas of STEM that they may not be exposed to at school (Brawley et al. 2008). Practitioners can represent professional institutions, voluntary organisations and Higher Education Institutions and, as they share their expertise and enthusiasm for STEM, they can reinforce students' knowledge and understanding in STEM subjects and awareness of STEM careers. Thus through this interaction, they can inspire, intrigue and motivate young people to study STEM subjects beyond their compulsory schooling and provide guidance on the possibilities of careers that can open up with a STEM qualification (Turner et al. 2007).

The students have access to outreach through two distinct connections: one initiated by an outreach practitioner and one by a STEM outreach facilitator. Through both types of contact, the practitioners can engage and communicate with students, share their passion towards the subjects and demonstrate the benefits of STEM subjects and careers (Laursen et al. 2007).

The outreach events can take many forms; they could be wider community public engagement events (e.g. The Big Bang Fair) or they could be student focused events (e.g. Bristol ChemLabs held at University of Bristol). Either the practitioner or a staff member from school/college could initiate the contact in order to organise the activity (e.g. FunMaths Roadshow of the Liverpool Mathematics Society). Some schools have designated coordinators while others do not. In such cases, either there is no initiation of engagement from schools/colleges with STEM outreach practitioners or there are teachers from a STEM subject that due to their interest, take the initiative and promote STEM enhancement and enrichment activities to their pupils.

The association between the practitioners and teachers is a two way process, as either can instigate involvement of students experiencing STEM outreach activities. Those that are triggered by the university/organisation often involve teachers deciding on who is given access to outreach. The selection process of students often follows given criteria (this may be due to the source of funding for the practitioner) which acts as a form of guideline, supporting teachers' decision of who is selected to engage in STEM outreach activities (Anon 2012).

In addition, there are established mediators taking on the role of external STEM outreach coordinators who also assist with the arrangements of organising STEM outreach activities. For example, STEMNET (who are an independent charity) support building connections between practitioners and school coordinators to promote and provide access to students on various types of outreach activities.

Some STEM outreach practitioners hold workshops to support and enhance teachers' understanding and knowledge of STEM subjects and careers. The key purpose of providing professional development training to teachers in STEM subjects is to develop their confidence, such that they are able to effectively add value to how students engage and interact during lessons in STEM subjects (Brawley et al. 2008; Anon 2012; Rivoli and Ralston 2009; Turner et al. 2007).

Furthermore, professionals from STEM industry can support or lead STEM outreach projects, and be part of the design and delivery process (e.g. the Ultimate STEM challenge organised by the BP Educational Service). Through young people engaging with employer led STEM outreach projects they can gain direct knowledge and expertise and gain first-hand experience. Further, employers' involvement in STEM outreach is vital, as they are those who will recruit and benefit from potential STEM graduates. Therefore maintaining strong connections with practitioners from the STEM industry can potentially be an effective way to promote STEM qualifications and the opportunities to young people and thus take on a significant place within the STEM outreach model (Mann and Oldknow 2012).

Figure 3.1 shows the STEM outreach model, incorporating those that are involved in delivering STEM outreach and its possible outcomes.

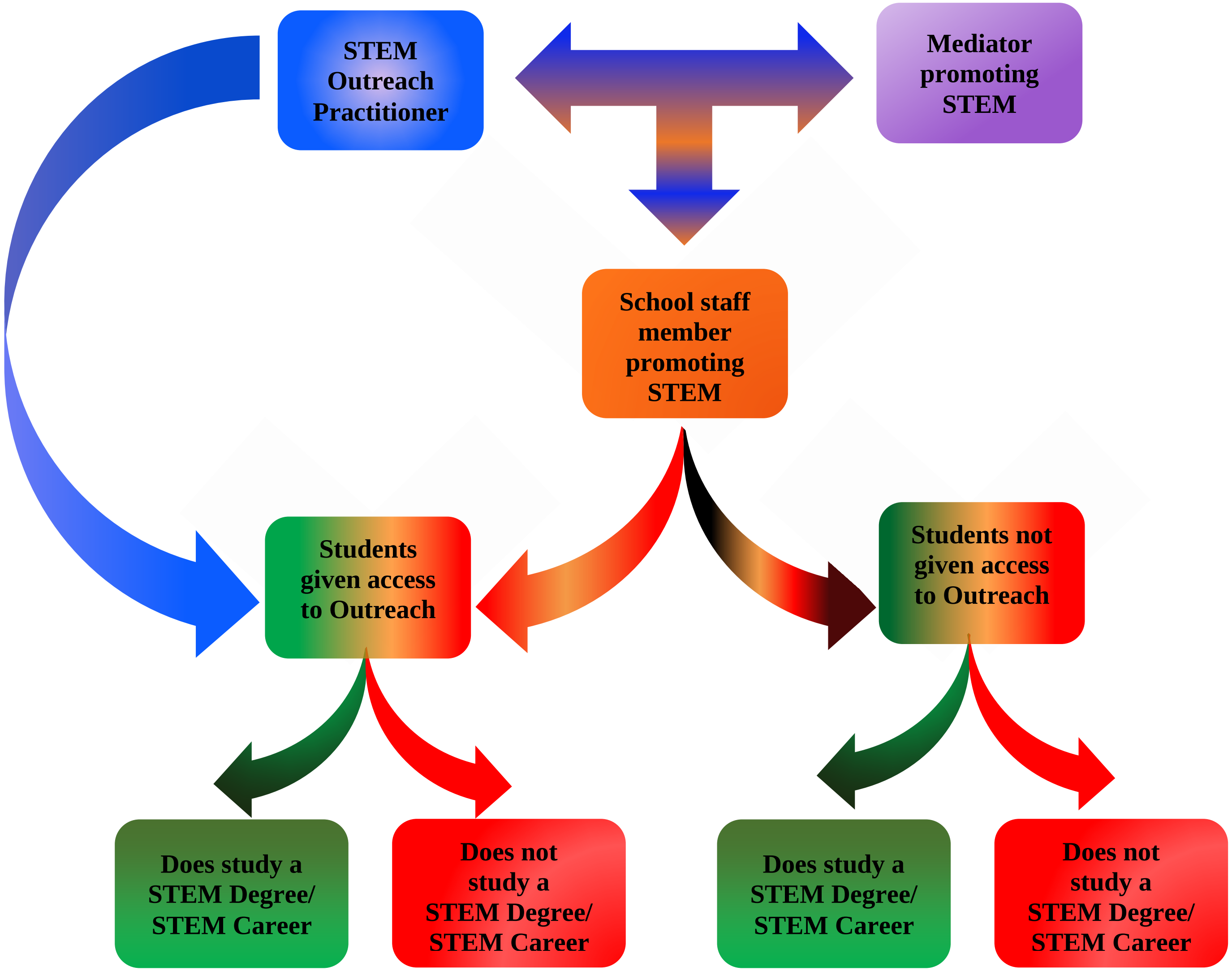

Figure 3.1: STEM outreach model

During this process, we identify a provider, a facilitator and a receiver through which the aims of delivering outreach are potentially met. Indeed, the provider is the STEM outreach practitioner, the facilitator in a school setting is the STEM outreach coordinating staff member (e.g. teacher in STEM) and the receiver is the student. In addition, in some instances, the mediator can also promote and influence the engagement between the practitioner and school pupils, thus taking the role of a supporter.

Table 3.1 summarises the relationships and characteristics associated with these specific four roles to further explain the STEM outreach model.

Contributor	Type of Role	Key Characteristics
STEM Outreach Practitioner	*Provider*	• Motivate students • Share passion • Create engagement • Enrich students • Provide teachers CPD opportunities
School staff member promoting STEM	*Facilitator*	• Selection of students • Selection of age groups • Selection of types of activities
Mediator promoting STEM	*Supporter*	• Support practitioners and schools to provide students access to a STEM outreach event
Student	*Receiver*	• Interest/disinterest developed towards STEM subjects • Impact of motivation and passion towards STEM career • No change - already engaged in STEM • No change - did not find STEM outreach effective

Table 3.1: A summary of the roles of the key contributors in STEM outreach

The STEM outreach model and the above table demonstrate how the role of a practitioner and particularly a teacher in STEM can influence the route of delivery as well as the content of the message communicated to the students. The messages the practitioners send should be strong and clear in terms of what they want the students to learn and experience. Students can receive and interpret this message directly from the providers. However, when this message is communicated through a facilitator, their role as a teacher allows them to decide on who they give the experience of STEM outreach to. During this process, for some students, the teachers can enhance the message or block the message, and hence give access to outreach to selective students only. A reason as to why this may occur is that often practitioners and schools have limited and specific funding which has been allocated to be spent on certain student groups, for example, top set year 9 girls. Hence, for this reason, teachers are sometimes unable to bring all students to outreach events.

The STEM outreach model shows two distinct sets of individuals: those that have engaged in STEM outreach and those who have not. In the end for all students it is their choice on whether or not they study a STEM degree and pursue a STEM career, though the effectiveness of the message received by the students from outreach activities can influence and support their decisions. Consequently, this research aims to investigate this aspect of STEM outreach further.

The significance of the roles of three key contributors in STEM outreach along with the process of communicating the message to students with a mediator has been presented. Following this, the students' education journey is explored to further understand and identify their key decisions points. As well as this, their key influences towards a STEM degree or career are discussed.

3.3 Identifying key decision points in a student's education journey

The education system in England requires students to stay in a form of education or training from the ages of 5 to 18 (DfE 2013a). During this period, the students encounter key decision stages which can support their future education and career choices (Golden et al. 2005; Straw and MacLeod 2013). The flowchart below shows the decision stages of an English student's education journey (see Figure 3.2). In addition, as the focus of this study is STEM outreach and how students' involvement in outreach activities influence their STEM degree and career aspirations, the flowchart includes details specific to STEM education.

At the end of year 9, pupils start making their first decision over the subjects they study for their Key Stage 4 post-14 options. Although students can take up optional STEM subjects such as GCSE computing, from a STEM perspective, this is a small decision as studying GCSE mathematics and science is compulsory. At the end of year 11 students make another decision and choose their Key Stage 5 post-16 options, which can range from academic (A levels) or vocational (e.g. Apprenticeship or BTEC Level 3) qualifications (Harrison 2012).

Once students have gained their post-16 qualification, they can then decide which route they would like to take, whether that is in education and training or work. To support their understanding of this next decision, there are online accessible career websites available for students as well as parents, teachers and careers staff to access (e.g. www.future morph.org and www.nationalcareersservice.direct.gov.uk), which provide advice for both GCSE and A level students. There are also guides that have been created by various professional institutions (e.g. see Tomorrow's Engineers and UCAS) to support students choices at various decision stages.

During this transition period, 14 to 19 year old students are required to make key decisions around their education which may impact on their future course choices and career paths. Thus, students of this age bracket are of key importance when studying the impact of outreach. Bostock and Wood (2012) state "14 has always been a crucial time in the development of young people". For these reasons, a key strategy was to involve students from the 14-19 age group in this research.

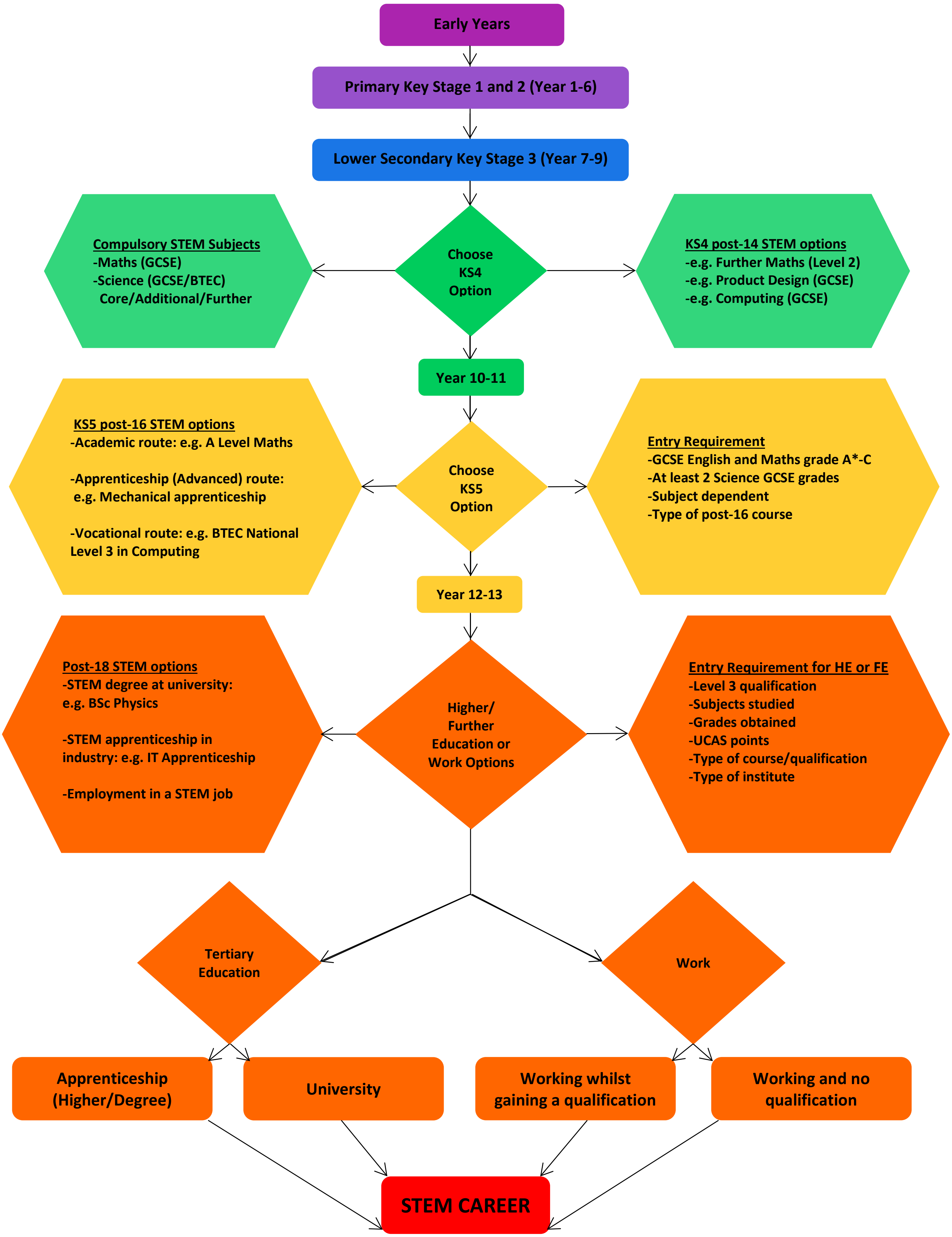

Figure 3.2: A flowchart demonstrating a student's education journey

3.4 Key influences during a student's 14-19 education journey

A vast range of research has been conducted seeking to understand key factors that influence students on their STEM education and career choices. A study carried out by Payne (2003) for the Department for Education and Skills reviewed the decision-making process and factors influencing post-16 choices. She found students' demographic background, students ability and the subjects they studied at GCSE, as well as advice from parents, career specialist and non-career specialist teachers, to be significant during this process. The Wellcome Trust (2010) also considered the significant factors for students aged 14 to 19 on their decision to study STEM subjects and found similar results (Tripney et al. 2010).

The Institution of Engineering and Technology (IET) (2008) investigated the "barriers to studying STEM" which reflected on the key attributes of teachers' and students' perception of STEM subjects. This review also highlighted the importance of the quality of teaching as well as the impact of parental advice towards STEM subjects and career choices. Another report summarised similar influential factors and additionally stated the relevance of students' interest and enjoyment of subjects as an indicator towards education and career choices (Hutchinson, Stagg and Bentley 2009).

A study conducted by University of Warwick (2011) looked into factors which were considered to potentially lead students to study a STEM subject at higher education. Along with the many factors mentioned above, they also found younger students (aged 13/14 and 14/15) were either keen or not keen to study STEM later in higher education, dependent on their perception of their own ability as well as their level of enjoyment towards the subject. In another study led by Foskett, Dyke and Maringe (2003) the factors influencing students' post-16 decision-making in a school setting were explored. Along with influences from teachers and career advisors, they also found external events such as work experience and talks from experts to play an important role in students' future choices. An illustration outlining these potential influences is presented below (see Figure 3.3).

Figure 3.3: An illustration of key influences along the three educational stages

Whilst the inner circle represents student characteristics/attitudes to STEM subjects and careers, the outer circle is largely factors that influence those characteristics/attitudes of the students. Although 'student ability' being a student characteristic is in the outer circle, it probably influences such things as understanding of STEM subjects and aspiration for a STEM career. These factors can have an influence at any stage (Wright 2005) of a students' education but my research will be addressing only the 14-19 stage.

3.5 Research questions

The purpose of this study is to evaluate and identify the effectiveness of STEM outreach from different perspectives, as well as describe the relationship between different stakeholders. Thus, the principle aim of the research is to independently explore the three key contributors involved in STEM outreach: practitioners, teachers and students, whilst combining their views and experiences to gain a deeper understanding of the complexity of their relationship (Creswell and Plano Clark 2007). The results include a comparative analysis of students who had and had not participated in STEM outreach. This comparison provides a measure of the differences in their level of understanding of STEM subjects and careers as well as their aspiration for a STEM career. The objective of capturing input from the practitioners and the teachers, is to gain a deeper understanding of their role as a provider and coordinator and thus explore their wealth of knowledge, views and experience as an outside and inside observer in STEM outreach.

The research questions that guide this study are:

RQ 1) What are practitioners' perspectives on student access and target year groups chosen for STEM outreach, the methodology of evaluation of outreach activities and its impact on students' views and understanding of STEM subjects?

RQ 2) What are teachers' perspectives on student access and target year groups chosen for STEM outreach, the methodology of evaluation of outreach activities and its impact on students' views and understanding of STEM subjects?

RQ 3) What are the students' perceptions of their understanding/lack of understanding of STEM subjects and careers? Is there a significant difference in the level of understanding of students who have participated in STEM outreach compared to other students?

RQ 4) Is there a significant difference in students' aspirations for a STEM career amongst those who have participated in STEM outreach compared to other students?

3.6 Research methodology

The philosophical position chosen for this research is pragmatic, which involves following a mixed methods research study to answer the above research questions (Greene, Caracelli and Graham 1989). Whilst this study uses a combination of both qualitative and quantitative research designs, a thorough consideration is given to the advantages and disadvantages associated with qualitative and quantitative research, along with their theoretical beliefs (constructivism and positivism) (Dzurec and Abraham 1993). The purpose and rationale for choosing this approach are discussed in detail in the following sections.

3.6.1 Qualitative research versus quantitative research

A paradigm also known as a worldview or perspective is said to define “a basic set of beliefs that guide action” (Guba 1990: 17). This set of beliefs determines how research is led and embraces philosophical ideas which contain foundations of epistemology, ontology, axiology and methodology assumptions. The differences within each paradigm influence our research culture (Johnson and Onwuegbuzie 2004). The paradigm creates a framework towards identifying and explaining what we know, outlines our view of reality and focuses towards our values and approaches in research (Morgan 2007).

Traditionally, both qualitative and quantitative research has been seen to be influenced by a particular paradigm and thus has guided the nature of the study through philosophical assumptions (Dzurec and Abraham 1993). For example, constructivism has been associated with qualitative research and positivism with quantitative research. In addition, each has been differentiated by the process of inquiry (induction or deduction) and, therefore, indicated distinct ways of collecting the data (Morgan 2007). Creswell and Plano Clark (2007) suggest the type of data collected, open-ended questions (e.g. text) or close-ended questions (e.g. numbers), signify the difference rather than the research method chosen (questionnaires or interviews). This is because there are qualitative research approaches such as ethnography which also implement questionnaires in their study as a method of data collection (Schensul, Schensul and LeCompte 1999).

Essentially, qualitative research is a form of inquiry which follows an inductive approach towards gaining a deeper understanding of individuals' experiences. Following a traditional social constructivist view, the purpose is to seek and interpret a phenomenon in a subjective manner. Here, the qualitative researcher is involved closely whilst collecting data in a natural setting and thus aims to develop his/her knowledge through interaction. This approach can also generate meaningful descriptive data on individuals' views along with identifying fundamental themes. Further to this, it is useful for describing complex phenomena as it focuses on how and why they occur (Johnson and Onwuegbuzie 2004).

In comparison to qualitative research, Morales (1995) suggests quantitative research is a process of explaining individuals' reality rather than understanding it. Taking a positivist approach holds the assumptions that we can objectively study a phenomenon through a deductive inquiry. Through this process, the relationship between variables can be measured and the behaviour of individuals can be defined. In addition, during this inquiry the researcher is considered to be uninvolved and independent and thus producing data which is unbiased and generalisable to a population similar to what is studied (Gall, Gall and Borg 2003).

As this study combines qualitative and quantitative research designs, their weaknesses as well as strengths are also highlighted. Although qualitative research focuses on a smaller sample compared to quantitative research, the process of data collection and analysis is considered to be very lengthy (Atkinson and Delamont 2006). In addition, even though the findings are rich and detailed, due to the nature of inquiry they are viewed to be neither generalisable nor replicable. Furthermore, it is often suggested the involved researcher does not allow the findings to be unbiased, as their presence can profoundly affect the outcomes. In comparison, quantitative research findings are viewed not always to generate unbiased findings as all participants may not understand and interpret the questions in the same manner.

Table 3.2 outlines and summarises the key characteristics of qualitative and quantitative research.

Type of research	**Qualitative research**	**Quantitative research**
Paradigm	Constructivism	Positivism
Purpose	Interpret a phenomenon through a subjective manner and understand an individual's reality	Interpret a phenomenon through an objective manner and explain an individual's reality
Outcome	Through a small sample, it produces rich, detailed, narrative descriptions and focuses on complex phenomena	Through a large sample, it produces generalisable, replicable, reliable and unbiased findings
Examples of traditional research methods	In-depth interviews or focus groups	Paper based or online questionnaires

Table 3.2: Key characteristics of qualitative and quantitative research

3.6.2 Mixed methods research

A paradigm brought into discussion by many research scholars (such as Peirce, James, Mead and Dewey) was pragmatism (Cherryholmes 1992). This worldview was introduced during the 19th century and as the debate between mixing qualitative and quantitative research approaches continued, the emergence of pragmatism became apparent resulting in a "third methodological movement" (Tashakkori and Teddlie 2003). This was seen as a philosophy taken by non-purist researchers that could "help bridge between the conflicting philosophies" (Johnson and Onwuegbuzie 2004). Nevertheless, many methodological purists disagreed with the compatibility of combining paradigms and instead suggested one should adopt one worldview, linked either with qualitative or quantitative when conducting research (Johnson and Onwuegbuzie 2004; Creswell and Plano Clark 2007).

Pragmatic philosophy builds on the assumption of developing knowledge through an abduction process and so forms a base for researchers who believe the truth is what works (Morgan 2007). To support this, Johnson and Onwuegbuzie (2004) suggest that taking an eclectic approach gives researchers freedom to be creative during the selection of research methods and, hence, encourages them to use methods that will provide the best solution to a research problem. In addition, this epistemology is not restricted by philosophical assumptions. Instead, it is positioned in the middle of constructivism and positivism, and so placing pragmatism as the third research paradigm.

Mixed methods research, is rooted in pragmatism. It unites multiple viewpoints, methods and approaches and has the strength to combine elements from both qualitative and quantitative research when appropriate (Johnson and Onwuegbuzie 2004), which traditionally has been the key reason for using this approach (Jick 1979). Also, many scholars such as Greene, Caracelli and Graham (1989); Bryman (2006); Collins, Onwuegbuzie and Sutton (2006) have identified other rationales for using mixed methods research. Some of the reasons expressed through their findings were developing triangulation, seeking completeness and answering different research questions.

Thus, incorporating this view for this study, the data from both qualitative and quantitative methods together have provided corroboration as well as an inclusive representation of the same phenomenon. In addition, this strategy has guided this research through a pluralistic and flexible approach and so enabled utilising all methods of data collection that were seen as the best way to answer the research questions. The practical aspect of this definition allows us to do this and, therefore, rather than using qualitative or quantitative data alone, this approach has supported the view of effectively studying the range of perspectives in STEM outreach (Creswell and Plano Clark 2007; Velez n.d.).

There are many benefits from mixed methods research. However, to understand a range of methods along with the approaches needed can be time consuming and incur higher costs. These factors make mixed methods research difficult. Procedures for collecting, as well as analysing qualitative and quantitative data can be complicated. The complications lead to challenges on how to appropriately combine various research approaches (Johnson and Onwuegbuzie 2004). Therefore, presentation becomes highly necessary in order to give a clear understanding of procedures and approaches.

3.6.3 Mixed methods research design

Adapting from Tashakkori and Teddlies' (1998) explanation, a mixed methods research design is developed for this research through combining elements of qualitative and quantitative strands. Furthermore, Creswell and Plano Clark (2011) developed a typology, which used the criteria: how mixing occurs, time orientation, the emphasis on approaches and the level of interaction involved (i.e. the two strands are independent of each other during the process of research or there is some form of interaction before the interpretation stage). Their approach formed six mixed methods designs:

1) "The convergent parallel design
2) The explanatory sequential design
3) The exploratory sequential design
4) The embedded design
5) The transformative design
6) The multiphase design"

This study opted for a convergent parallel design and gave equal emphasis to both qualitative and quantitative strands. As well as collecting the data simultaneously, the analysis of the data took place independently and the findings from both strands were merged during the interpretation stage. The reason why the mixed methods design, convergent parallel design outlined by Creswell and Plano Clark (2011), is chosen for this research is due to the clear emphasis on the stages of merging and interpretation as this technique of combining the two separate results is a key focus of this study. In addition, their diagram illustration provided in Figure 3.4 is a strong and clear representation of the model, which has supported and guided the adoptation of the design for this research.

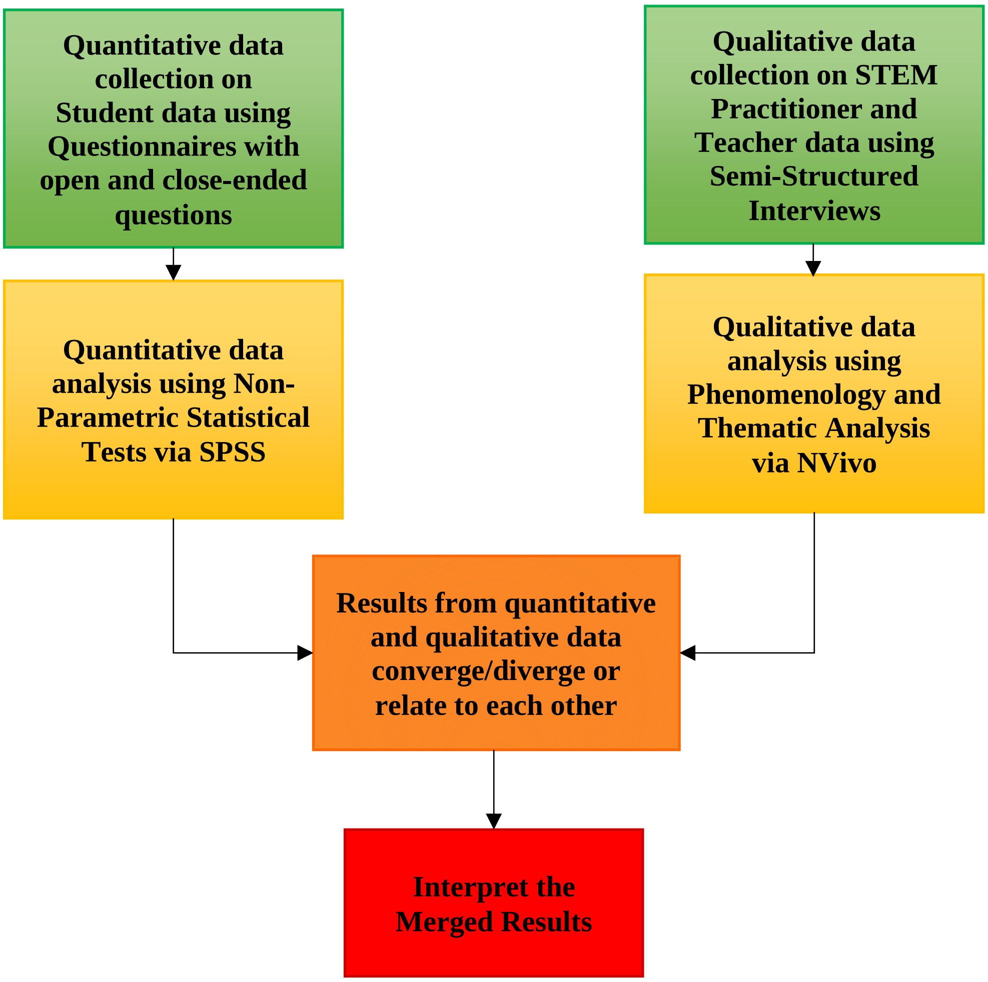

Figure 3.4: Mixed methods design adopted for this study from Creswell and Plano Clark's (2011) typology

Thus, a convergent parallel design, rooted from the concept of triangulation (Jick 1979), was chosen as data from both strands was collected and analysed at separate stages and then combined together to form a mixed methods research design. The key purpose for using this design was to produce complementary quantitative and qualitative findings through integration and interpretation of the results. Giving both strands equal weighting was significant and by using different data collection techniques, the view of gaining a deeper understanding of the effectiveness of STEM outreach through various perspectives was supported (Creswell and Plano Clark 2011).

After independently collecting and analysing qualitative and quantitative data, the results are merged revealing how they are connected and/or disconnected. Thus, combining the views and experiences of all three key contributors of STEM outreach: (practitioners, teachers and students), the complexity of their relationship was explored and highlighted.

3.7 Qualitative research method

A key aim of this study was to explore and describe practitioners' and teachers' experiences of delivering and coordinating STEM outreach. Gaining their own perspectives on their roles was viewed to be valuable and important, addressing RQ 1 and 2 (see section 3.5). Using a qualitative research strategy, an interpretation of their views was formed.

The approach that was adopted to guide this research was phenomenology. Taking this research approach meant "describing the meaning of the lived experience for several individuals about a concept or phenomenon" (Creswell 2007). This definition was similar to Patton's (1990) as he suggested through this approach, an account is formed about those who experience what they experience. Hence, implying that reality is captured through engaging with those close to the phenomenon of interest.

Therefore, the main purpose of following this approach was to subjectively understand practitioners' and teachers' experience of STEM outreach through their points of view; their wealth of knowledge and their expertise in this field, as well as their perspective of the impact on student engagement in outreach was of most interest.

The advantage of following this approach was the ability to gather descriptive meanings of participants' experiences in a natural setting (Creswell 1994). In addition, it provided an opportunity for the key contributors to express their views on matters that were of importance to understand the effectiveness of STEM outreach. However, taking this approach meant the findings were not generalisable, though this was counteracted through gaining rich and detailed experiences of the practitioners and teachers involved in STEM outreach.

The qualitative method chosen for data collection was in-depth interviews, as this tool can facilitate discussions and let participants “express how they regard situations from their own point of view” (Cohen, Manion and Morrison 2011). A rationale given by Denscombe (2007) also supported the purpose of this study, as he suggested using this method to investigate opinions and experiences. In addition, Robson (2002) also described how interviews can be integrated with other research methods in order to support the overall findings. Thus, through the combination of qualitative and quantitate data collection tools, the findings can be corroborated.

A key characteristic, which distinguishes this research method, is the range of interview questions. Robson (2002) provided an explanation of three types of interviews:

• ***Fully structured interview***

-This involves pre-established questions with fixed wording. The questions are set and asked in a specific order and this cannot be altered.

• ***Semi-structured interview***

-This involves pre-established questions but the wording and the order of the questions can be altered. These changes can be implemented during the interview process based on the situation.

• ***Unstructured interview***

-This involves the most flexibility as this style of interview has no set dimensions and is rather based on the flow of the conversation. It intends to focus on a general area of interest and generates open-ended questions and responses.

For the purpose of this study, semi-structured interviews were used as this provided a moderate flexibility towards gaining responses which were rich and meaningful. Also having the ability to modifying the order as well as change the pre-set questions provided a rationale for choosing this approach.

3.7.1 Development of instrument for teacher and practitioner data collection

Careful consideration was given to certain guidelines, which assisted the overall process of designing the interview questions for STEM outreach practitioners and teachers. Robson (2002) outlined two key areas:

1) Focus of the questions

Patton (n.d.) identified certain areas that can be taken into consideration and these were:

- "Behaviours - about what a person has done or is doing
- Opinions/values - about what a person thinks about a topic
- Feelings – about what a person feels
- Knowledge - to get facts about a topic
- Sensory - about what people have seen, touched, heard, tasted or smelled
- Background/demographics - standard background questions, such as age, education, etc"

As the purpose of interviewing STEM outreach practitioners and teachers was to investigate their involvement as well as understand their experience in outreach, focus was given to all six topics of questions types (see Appendices A and B for a copy of the practitioner and teacher interview questions).

Table 3.3 illustrates the themes used in the data collection tool for STEM outreach practitioner and teacher interviews and how they associate with the question focus identified by Patton (n.d.).

Key themes from the Practitioner and Teacher interview questions	**Topics associated with**
Background information	Background/demographics
Why an interest in STEM outreach	Opinions/values
Selection process of students	Behaviour, knowledge
Design of outreach activities	Behaviour
Identifying the effectiveness of outreach activities	Sensory, opinions/values, feelings, knowledge
Evaluation methodologies	Sensory, opinions/values, feelings, knowledge

Table 3.3: Key themes of practitioner and teacher interviews and the focus of the questions

This study aimed to seek their knowledge, gain facts as well as understand their thinking process and investigate their behaviour. Also of interest was exploring their opinions on the topic, their emotions and how they view and see things. However, asking them to reflect on their past experience can be challenging, but through giving direct focus to the questions, useful responses can be generated.

2) The content of the interview design

This should be developed prior to the interview and, therefore, facilitate the overall process of interviewing. Robson (2002) identified two main types of questions used in an interview: open-ended questions and closed-ended questions.

The use of open-ended questions provides a greater scope for discovery as the discussions are unrestricted and so the respondent is free to express, interpret and respond to the question as they want. An example of this type of question was: "*What are your views on outreach?*"

Whereas, the use of closed-ended questions is direct and set responses which are required to be chosen from a list of options. An example of this type of question was: *"Were you involved in the design process?"*

As the qualitative research method took a phenomenological approach, the concept was to create opportunities for the respondents to share and express their experience and so mainly open-ended questions were used (Penner and McClement 2008).

Overall, the focus and the content of the questions were given great attention prior to and during the development of the tailored practitioner and teacher interview questions. There were certain types of questions which were avoided. These included long, leading and biased questions, also questions which asked for multiple responses as well as questions which were thought may not be understood by the respondents. These guidelines set by Robson (2002) guided this study and efficiently enabled the development of clear, concise and flexible interview questions. In addition for each set of interviews sub-questions were formed to support the expansion of the interviewees' responses in an effective manner.

3.7.2 Sampling and data collection techniques for qualitative data

The primary aim was to obtain in-depth information from those who are able to provide it rather than information which would generalise and be representative of the wider population (Creswell 2007). Hence, it was important to identify practitioners and teachers who were actively involved in STEM outreach and had great experience of working in this field.

For this research, purposive sampling was chosen as this sampling method concentrated on collecting views and ideas from a diverse population of practitioners and teachers who were involved in STEM outreach (Cohen, Manion and Morrison 2011). Their specific knowledge and expertise were the phenomena of interest. A deeper insight was anticipated on the factors they take into consideration when delivering and coordinating STEM outreach activities.

A STEM outreach practitioner does not normally focus and cover all areas of STEM disciplines whilst delivering outreach activities. This is because each practitioner has their own subject speciality and so the practitioners in STEM disciplines can vary with respect to their subject expertise. Due to this reason, the sample of STEM outreach practitioners included chemistry, biology, physics, computing, engineering and mathematics outreach providers. This was similar to the teacher interview sample, though the focus was kept primarily on teachers who taught science or mathematics to students aged 11+ (year 7 - year 13) in a school/college.

For the qualitative data collection, the practitioners and teachers were emailed at the beginning of July 2014 with a request to participate in this study. They were given information in the email about how their involvement would significantly support this study and an outline of the overall purpose and nature of the interview. In addition, as the request was for a face-to-face interview, it was important to conduct these in an environment where the interviewee felt most at ease. Thus, meeting arrangements were made according to the interviewee's preference and normally the interviews took place at the teacher's school, the practitioner's workplace or at a nearby café.

3.7.2.1 STEM outreach practitioner participants

The practitioners for this study were a sample of external providers of an outreach initiative or were working in Higher Education. Each provider had an extensive amount of experience of delivering outreach to students in various STEM disciplines. This information was gathered through various published reports as well as through the web link provided by the National Higher Education STEM Programme (http://www.hestem.ac.uk). The period for collecting qualitative data from the practitioners was from September 2014 to February 2015. In total, in-depth qualitative data were collected from sixteen STEM outreach practitioners.

3.7.2.2 Teacher participants

Some of the teachers who agreed to be interviewed also gave permission to collect quantitative student data from their schools/colleges. This facilitated the process of data collection concurrently as qualitative and quantitative data were collected from teachers and students. Coinciding with collecting the quantitative student's data, the duration of conducting the teacher interviews was between July 2014 and October 2014 and in total, in-depth qualitative data were collected from ten teachers each of whom had the role of a STEM outreach coordinator for their school/college.

3.7.3 Qualitative data analysis technique

Recording of the interviews took place after obtaining permission from the respondents. This process was facilitated through an inbuilt voice recorder on a smartphone, which once recorded was transcribed and saved into a Microsoft Word document. Gathering all interview transcripts onto a database allowed the use a computer software package known as NVivo. This assisted with the analysis of the qualitative data as the software operated as a platform to help navigate between the large quantities of qualitative data generated from the interviews (Arthur et al. 2012).

For this study, the strategy chosen to analyse the qualitative data were thematic analysis (Bryman 2012). This is described by Braun and Clarke (2006: 79) as a "method for identifying, analysing and reporting patterns (themes) within data". In other words, it is a method for capturing central themes, which are important towards describing the phenomenon of interest (Daly, Kellehear and Gliksman 1997); thus, seeking to discover patterns, gaining an insight and developing an understanding of the themes that are occurring are the essential purposes of this applied tool.

Previous studies have supported the use of this strategy in a phenomenological approach (Braun and Clarke 2006; Fereday and Muir-Cochrane 2006). This is because the thematic analysis is primarily a method (i.e. tool) and so it is not guided by pre-determined epistemological values. Therefore, the use of this strategy as a flexible analytic tool can be utilised in a mixed methods research approach.

Braun and Clarke (2006) provided a six-step guideline on how this tool is applied to analyse a qualitative data set. Below each step, a brief description is provided to illustrate how these steps were incorporated into the analysis of the practitioner and teacher interview data sets.

1) Familiarising yourself with your data

Being actively involved during the process of data collection and analysis supported the development of the base understanding of the data. Through reading the transcribed documents, a thorough sense of the data were gained.

2) Generating initial codes

With the support of NVivo, initial codes were identified and used to assist with the analysis stage. These codes were generated using a systematic approach and were key towards classifying patterns in the data set.

3) Searching for themes

During this stage, the identified codes along with the extracts of data were collated to form relevant themes.

4) Reviewing themes

The themes generated were reviewed and refined for the purpose of checking their accuracy in relation to the data set and this was re re-read to provide further insight into the developed themes. This assisted with validating the current themes as well as identifying the need for new themes. The process of this phase was supported by the development of a thematic map.

5) Defining and naming themes

The themes were investigated in more depth as during this stage they were defined to gain a deeper meaning as well as initiate reasons as to why they were of most interest. In addition, the themes were refined to support the ongoing analysis process and presentation of the data sets and throughout workable themes were formulated.

6) Producing the report

A detailed counterbalanced write-up was produced to provide vivid and compelling accounts of the data and demonstrate how the key themes related to the research questions.

The descriptions under each phase illustrate the steps that were taken to conduct thematic analysis for the qualitative data sets.

The limitations were also considered during the process of this analysis. Careful thought was given towards capturing a true reflection of the data as many scholars, such as Joffe and Yardley (2004: 67), explain how the themes should "describe the bulk of the data" and not just a particular instance. Thus, the extracts chosen were those that presented a detailed meaning of the entire data set. Another drawback with this method is having the ability to analyse in a manner that is effective and accurate. Therefore, to address this, constant reviewing of the codes and the themes all through the phases of analysis was carried out.

3.8 Quantitative research method

A key aim of this study was to explore students' perceptions, understanding of and aspirations for STEM subjects and career paths, comparing those who had participated in STEM outreach to those who had not. Hence, in order to conduct a comparable study, a quantitative research strategy was adopted, addressing RQ 3 and 4 (see section 3.5).

As a result, the research method chosen for student data collection was questionnaires (also known as surveys). This method was most appropriate for effectively collecting feedback from students on their experience of STEM outreach, as well as capturing a "numeric description of trends, attitudes, and opinions" of all students involved in this study (Arthur et al. 2012; Creswell 2008). Also referring to the illustration, STEM outreach model (see Figure 3.1), it was outlined how students' exposure to outreach varied, therefore, by simultaneously comparing both groups of students, provided quantifiable findings on the overall impact and effectiveness of STEM outreach.

The use of a questionnaire to collect quantitative data from students has provided meaningful measurable data. A statistical insight into their behaviour and attitude towards certain events was gained. In addition, through this method, it was relatively easy and quick to gather large amounts of primary data. This also facilitated conducting a mixed methods concurrent parallel study, by collecting the qualitative data roughly at the same time (Creswell and Plano Clark 2011).

A drawback with using this technique of data collection was associated with the potential ambiguity of some questions, with students possibly interpreting some questions differently. The possibility of a low response rate was another issue as it can be difficult to get respondents to fully complete the questionnaires. Another drawback is the reliability of the responses provided by the students. This could be due to various reasons, for example students' lack of memory on the subject or their lack of understanding on the question. Further this approach may not be sufficient to use to understand complex issues though may support the researcher to identify and capture an overall insight to the problem investigated. There is also a possibility of gaining responses from a bias sample as those interested and/or involved in STEM activities may provide a thorough and in depth response than those students otherwise Bryman (2012)

3.8.1 Development of instrument for student data collection

The focus of understanding the impact of outreach led this research to explore students who recently had experienced making a key decision (students aged 14-19). Potentially being at a point where they could process their thoughts towards considering higher education and career routes, views of students who were studying for their post-14 (aged 14-16) and post-16 (aged 16-18) qualifications as well as a STEM undergraduate degree qualification (aged 18+) were captured. Although for each educational stage group, a tailored questionnaire was designed, the key characteristic of each instrument are similar (see Appendices D, E and F for a copy of the GCSE, A level and STEM undergraduate questionnaires).

Many factors are taken into consideration for the development of an instrument for collecting student data. Blaxter, Hughes and Tight (2006) identified seven types of questions through which data can be collected, which include: “quantity or information, category, list or multiple choice, scale, ranking, complex grid or table and open-ended”.

The questionnaires have included six of the seven question types:

• ***Quantity or information*** questions allow the responses to be written rather than chosen from a set menu. For example, the students were asked to provide information on the name of their school.

• ***Category*** questions provide basic though useful information. Examples of these types of questions had responses such as “yes/no” or “male/female”.

• ***List or multiple choice*** questions are advised to be used if the researcher is aware of all possible outcomes. To support this, the option of “other, please specify” is given so that respondents can convey their response if not present in the set categories (Oppenheim 1992). Here, the questionnaire has asked students to select “all that apply” and so more than one response can be selected from the list provided.

• ***Scale*** questions also known as Likert-type questions are commonly used to measure opinions. They can vary in terms of the number of categories, such a question may utilise a four-point scale question or a five-point scale question. Using an even number of responses means there is no middle opinion, for example “neither agree nor disagree”. This is held to produce a thought-provoking response though can be seen as forcing a decision as well. On the other hand, in an odd number of response question, there is a neutral category, which then gives respondents a choice of not having an opinion. However, not gaining a degree of opinion can also be viewed as a drawback. Nevertheless, both types of Likert scale questions have been used as according to Garland (1991), the choice of using an odd or even Likert scale should be “content specific”.

• ***Ranking*** questions are recommended if a preference of opinion is desired. For example, “please rank the categories in order of importance, where 1 is most important and 5 is least”. This type of question can support with answering what categories are most and least favoured.

• ***Open-ended*** questions are useful in questionnaires as they allow the respondents to share and express their opinions in text format, though the analysis of this type of question can be difficult (Gillham 2007).

From the above types of questions: category, list or multiple choice, scale and ranking are examples of closed-ended questions.

Due to the age of the student participants, great emphasis was given to the clarity of question wording. Burgess (2001) stated guidelines to follow when forming the wording of the questions. This include:

• “Be concise and unambiguous
• Avoid double questions
• Avoid questions involving negatives
• Ask for precise answers
• Avoid leading questions”

It is important that the wording is clear and reflective of the true question to be asked. Thus, being explicit with the wording is much preferable to asking questions which may be interpreted differently. In addition, the questions should be least confusing and so avoiding the use of double questions. For example, “Do you understand STEM subjects and careers?” It is not necessarily true that both questions have the same response and so the wording must change and let this take the form of two separate questions instead. Also, leading questions and the use of negative wordings should be avoided. Thus, the language used in a question is important to avoid difficulties whilst completing the questionnaire. Additionally, where possible gaining a precise answer is desirable as this can support the data analysis and interpretation stage.

Bryman (2012) suggested avoiding the use of technical terms. Hence, whilst developing the questionnaires, a concern was raised about students' understanding the term 'STEM outreach', which would mean they would not be able to provide an accurate response to whether or not they had previously participated in STEM outreach activities. To address this issue, the student questionnaires used the phrase "extra-curricular Science, Technology, Engineering and Mathematics (STEM) activities" instead. In addition, students were referred to a specific question on the questionnaire that included a list of examples of potential STEM activities.

Thus in summary, in order to ensure clear and plausible questions were developed, key focus was given to the wording of the questions.

Careful consideration was also given to the layout and the sequential order of the questions. With the intention of "facilitating the answering of the questions", a clear layout and order were established to support the respondents to effectively comprehend what is being asked (Dillman, Smyth and Christian 2009; Bryman 2012). Oppenheim (1992) suggested that having a presentable questionnaire that showed logic and was easy to follow can also assist with gaining a higher response rate.

The order of this tool was formed systematically. Initially, students' demographic and socio-economic background information was collected. This was then followed by gaining insight into the STEM subjects they enjoyed, as well as what their key decisions and influences were. A significant aspect of developing the quantitative tool was to provide the students a platform to share their experience of previous STEM outreach activities. Whether or not students had previously participated in outreach was explored. Of those that said "yes" to participating in STEM related activities, further questions were asked to gain a deeper insight into their overall experience. Some of the preliminary questions were: which school year did this happen in, the number of sessions they attended and on average how long their activities were. In addition, they were asked to provide a brief description of what they did during the activities and which of the four STEM areas (science, technology, engineering, and/or mathematics) their activities related to. The connecting questions were presented in a sequential manner, in an attempt to encourage the participants to reflect on their previous experience, by recalling their involvement in any STEM extra-curricular activities. Students' level of understanding of STEM subjects was explored as well as academic stages at which they considered themselves to comprehend STEM professions. The questionnaires concluded by gaining students' perceptions of STEM subjects along with any recommendations for how the younger generation could be encouraged to study STEM at university.

The questionnaire that was used as the tool for collecting quantitative data from those studying their GCSEs is presented below (see Figure 3.5).

1. a) Name of School/College: ______________________________ b) Gender: Male ☐ Female ☐
2. a) Ethnicity: ☐ ***Please check on the last page for ethnicity code*** b) UK National: Yes ☐ No ☐
3. Household Income: **(Tick <u>one</u> only)** £10,000 - £20,000 ☐ £20,000 - £30,00 ☐ Over £30,000 ☐
4. Are you entitled to Free School Meals? Yes ☐ No ☐
5. Has one or more of your parent(s)/guardian(s) completed a University degree? Yes ☐ No ☐
6. Please provide the first 3 characters of your postcode: ________________ ***(For example CV1)***
7. List the GCSE **subjects** you are currently studying **and** note the **grade** you have been predicted for each subject in the box provided:

1. ___________________ ☐	5. ___________________ ☐	9. ___________________ ☐
2. ___________________ ☐	6. ___________________ ☐	10. ___________________ ☐
3. ___________________ ☐	7. ___________________ ☐	11. ___________________ ☐
4. ___________________ ☐	8. ___________________ ☐	12. ___________________ ☐

8. Which subjects do you enjoy/find interesting? **(Tick <u>all</u> that apply)**

Mathematics ☐ Chemistry ☐ Biology ☐ Physics ☐ Environmental Science ☐ Astronomy ☐
Electronics ☐ Design and Technology ☐ ICT ☐ Computing ☐ Engineering ☐ None ☐

9. After finishing your GCSEs, what are you planning to do next? **(Tick <u>one</u> only)**

A levels ☐	BTEC course ☐	Diploma ☐
Applied A levels ☐	NVQ course ☐	International Baccalaureate Diploma ☐
Apprenticeship ☐	Traineeship ☐	Not sure yet ☐
Part-time education or training whilst working/volunteering ☐		Other *(please specify)* ____________________ ☐

10. At what academic stage did you become sure about what you wanted to do after finishing your GCSEs? (Tick **<u>one</u> only)**

Before Year 6 (Primary) ☐ Year 7-9 (Lower secondary) ☐ Year 10-11 (GCSEs) ☐ Still not sure ☐

11. Who or what do you see as the major influence on your course choice? **(Tick <u>one</u> only)**

Parents	☐	Family Members	☐	Interest/Enjoyment of Subject	☐
Teachers	☐	You're good at it	☐	Extra-Curricular Activities	☐
Friends	☐	Personal Choice	☐	Still not sure	☐
Career Fairs	☐	Work Experience	☐	Other *(please specify)* ____________________	☐

12. Are you thinking of having a career which is Science, Technology, Engineering and/or Mathematics related?

Yes ☐ No ☐ *If you know what you want to be please share:* ______________________

13. How sure are you about the career you want to pursue after finishing your GCSEs? **(Tick <u>one</u> only)**

Very sure ☐ Quite sure ☐ Neither sure nor unsure ☐ Quite unsure ☐ Very unsure ☐

14. Did an internal or external adviser visit your school or did you visit an institution to help you understand the available options following your GCSEs?

Yes ☐ No ☐

If Yes, which **School Year(s)** did this happen in? ____________

15. At school, have you taken part in **extra-curricular** Science, Technology, Engineering and Mathematics (STEM) activities? **(See Question 19 for a list of examples of STEM activities - If unsure please ask)**

Yes ☐ No ☐ ***If No, please go to Question 28***

If Yes, which **School Year(s)** did this happen in? ____________

16. Number of sessions you attended *(estimate):*1 session ☐ 2-5 sessions ☐ 6-10 sessions ☐ 10+ sessions ☐

17. On average, how long were the activities? **(Tick <u>one</u> only)**

1 hour ☐ 2 hours ☐ Half a day ☐ 1 day ☐ More than 1 day ☐

Please give brief details of what you did in the activities:

____

____

18. Which subject(s) were the activities related to? **(Tick <u>all</u> that apply)**

Science ☐ Technology ☐ Engineering ☐ Mathematics ☐

19. What type of STEM activities did you do? **(Tick <u>all</u> that apply)**

STEM days	☐	STEM Ambassadors events	☐	Master classes/lectures	☐
Competitions	☐	Attended seminars	☐	Undergraduate shadowing	☐
Taster courses	☐	Mentoring schemes	☐	Hands on interactive placement	☐
Careers academy	☐	Summer placement	☐	Other *(please specify)* _____________	☐

20. If you've done more than one, which activity did you enjoy **most** from those that you ticked in Question 19? **(Tick <u>one</u> only) –** ***If only done one type of activity, please go to question 22***

STEM days	☐	STEM Ambassadors events	☐	Master classes/lectures	☐
Competitions	☐	Attended seminars	☐	Undergraduate shadowing	☐
Taster courses	☐	Mentoring schemes	☐	Hands on interactive placement	☐
Careers academy	☐	Summer placement	☐	Other *(please specify)* _____________	☐

21. If you've done more than one, which activity did you enjoy **least** from those that you ticked in Question 19? **(Tick <u>one</u> only) – *If only done one type of activity, please go to question 22***

STEM days	☐	STEM Ambassadors events	☐	Master classes/lectures	☐
Competitions	☐	Attended seminars	☐	Undergraduate shadowing	☐
Taster courses	☐	Mentoring schemes	☐	Hands on interactive placement	☐
Careers academy	☐	Summer placement	☐	Other *(please specify)* ____________	☐

22. How interesting were the activities? **(Tick <u>one</u> only)** Very interesting ☐ Ok ☐ Boring ☐

23. Overall, did you enjoy the activities? **(Tick <u>one</u> only)**

Not at all ☐ A little ☐ Quite a bit ☐ Very much ☐

24. How much awareness and knowledge did you gain about STEM related subjects? **(Tick <u>one</u> only)**

Not at all ☐ A little ☐ Quite a bit ☐ Very much ☐

25. How much influence did this make towards your decision of further studying STEM related subjects after completing your A levels? **(Tick <u>one</u> only)**

Not at all ☐ A little ☐ Quite a bit ☐ Very much ☐

26. Due to taking part in STEM activities, are you more likely to consider a career in STEM than you might have before? **(Tick <u>one</u> only)**

Not at all ☐ A little ☐ Quite a bit ☐ Very much ☐

27. How could the activities have been improved? **(Tick <u>all</u> that apply)**

More interaction	☐
Better organisation	☐
Made it more fun	☐
Having enthusiast and engaging STEM practitioners	☐
Providing more information about STEM subjects	☐
Providing more information about STEM degrees	☐
Providing more information about STEM careers	☐
Providing more information about how STEM relates to real world	☐
Other *(please specify)* ______________________________	☐

28. As a whole, how much do you understand about the following subjects? *Please be honest* **(Tick <u>one</u> response for each subject)**

Subject	**Not at all**	**A little**	**Quite well**	**Very well**
Engineering				
Computer Science				
Mathematics				
Physics				
Chemistry				
Biology				

29. In what academic year did you clearly understand what the following professions actually do? *Please be honest* **(Tick <u>one</u> response for each profession)**

Professional areas	Before Year 6 (Primary)	Year 7-9 (Lower Secondary)	Year 10-11 (GCSEs)	Still don't know
Engineers				
Computer Scientist				
Mathematicians				
Physicist				
Chemist				
Biologist				

30. In few words can you express your opinion on the following areas: ***(For example, Engineering: It's fascinating when you discover how something works due to the maths and science behind it OR It's not very interesting OR I don't really know much about it OR I love a challenge and this is exactly it!)***

Science:	Computing/Technology:
Engineering:	Maths:

31. If you have any ideas of how we could encourage more young students to apply to study Science, Technology, Engineering and Mathematics (STEM) subjects at university then please provide details below:

Figure 3.5: GCSE student questionnaire

A similar questionnaire was developed for A level and STEM undergraduate students (see Appendices E and F for a copy of an A level and STEM undergraduate questionnaires respectively). Table 3.4 details a summary on the type of questions that were explored for those students studying their GCSEs, A levels and STEM undergraduate degrees. This table outlines the variations in the questions type, a cross (x) has been given if the questionnaire included the question and a dash (-) if otherwise.

Six key areas were explored across all three student questionnaires. These include demographic information, key decisions and influences on course and career choice, student experience and impact of STEM outreach, their level of understanding of STEM subjects and professions, enjoyment/interest towards STEM subjects, student perceptions of STEM and future recommendations to encourage the next young generation to study STEM subjects further in higher education.

Each questionnaire was designed to capture information on a student's involvement in extra-curricular STEM activities in great depth, as well as other key aspects such as their level of aspiration for a STEM career. For those studying their GCSEs and A levels, out of the total of thirty-one questions, thirteen questions were associated with STEM outreach (see questions 15 to 27 on GCSE and A level student questionnaire respectively) and for those studying a STEM undergraduate degree, out of twenty-four eleven concerned STEM outreach (see questions 10 to 20 on STEM undergraduate student questionnaire).

The questionnaires were distributed to students using a technique associated with a higher response rate. This was reported by Bowling (2005) during her review on different methods of administering questionnaires. Brown (2001) described two methods of delivering questionnaires: self-administration or group administration. Postal delivery of a questionnaire is an example of a self-administrated questionnaire as the respondents can complete this in their personal time and return once completed. Whereas with group administrated questionnaires, the researcher is able to collectively distribute them in a group setting and if needed provide students an opportunity to ask questions for clarification purposes (Bryman 2012; Zohrabi 2013). Therefore, for the purpose of this study, the technique of group administration was considered most appropriate as it also involved the researcher being active during the process of data collection. Thus, student data were collected through a paper-based questionnaire.

Details of type of questions in all student survey		GCSE	A level	Undergraduate
Demographic data	Gender	x	x	x
	Ethnicity and UK National	x	x	x
	Entitled to free school meal	x	x	-
	Parent/Guardian completed University	x	x	-
	Postcode	x	x	-
	List of subjects currently studying	x	x	-
	Type of recent qualification	-	-	x
	Decision after completing GCSEs/A levels	x	x	-
Key decisions and influences	Awareness of career choice	x	x	x
	Academic stage of course sure	x	x	x
	Access to an advisor for course/career guidance	x	x	x
	Primary source of influence	x	x	x
STEM outreach	Participate in STEM outreach and further details asked	x	x	x
Level of understanding	Level of understanding towards STEM subjects	x	x	x
	Academic stage of understanding STEM professions	x	x	x
Enjoyment/ Find Interesting	Enjoy/interesting STEM subjects	x	-	x
Perception of STEM and future development ideas	Views on STEM	x	x	-
	Views on encouraging more students to study STEM at university	x	x	x

Table 3.4: Summary of question types for GCSE, A level and STEM undergraduate students

3.8.2 Sampling and data collection techniques for quantitative data

Probability sampling (for example, random sampling) is a preferred sampling strategy for quantitative research methods. However, Creswell (2014: 76) highlights how this may not always be the case due to the nature of the data collection method and so, if appropriate, a non-probability sampling technique can be adopted.

For this study, teachers from several schools/colleges were initially approached and a request was sent via email to ask for their support for the process of the student (under the age of 18) data collection. For those teachers that showed willingness, further arrangements were put in place and data from students studying in Key Stage 4 and 5 was collected. As data from students situated in school settings was to be collected, i.e. from "naturally formed groups", a convenience sampling strategy was seen as most appropriate for this study. Therefore, as the quantitative research method took a non-probability sampling approach, the sample of students was not entirely random (Creswell 2003: 164).

The teachers were emailed at the beginning of July 2014 and October 2014 for approval for their students to participate in this study as they have a very tight teaching schedule throughout the school term. Therefore, they were approached later or earlier in the year to avoid a high proportion of teachers refusing to take part in this research due to their workload. Also, this was seen as a way to increase the prospect of securing an interview with teachers involved in STEM outreach. Initially, teachers were approached later in the academic year (July 2014) and many students in year 11 had already completed their GCSEs and so were not present in school. As a result, the collected data in July 2014 mainly consisted of those students in year 10 going into year 11. On the other hand, student data collected earlier in the academic year (October 2014) contained students in years 10 and 11. Student data collection for post-16 students was also similar as by July, the majority of year 13 students had completed their A levels and so left sixth form/college. Thus, most of the data were collected from students in year 12 going into year 13.

Overall, 12 school/college teachers gave permission for data to be collected from their Key Stage 4 and 5 students. In addition, some Key Stage 5 student data were collected by attending careers events organised by local universities. Thus, a large sample of year 12/13 student data were gathered by the researcher attending events, which, in effect, assisted with capturing data from a variety of schools/colleges based in England. It is important to maintain precision with any forms of sampling methods and, therefore, a key objective whilst using this sampling technique was to capture data from as many schools/colleges as possible. Thus, this approach facilitated overcoming the concern of similarity and diversity within the target population and involved students from various demographic and socio-economic backgrounds, providing variation in the data sampling set.

In addition, gathering data from the first year STEM undergraduate students took place with the support of staff members from various higher education STEM courses. In September, before university courses commenced, staff members were sent an email asking for their consent and, where permission was given, data were gathered during students' induction week. This process of data collection occurred during the period 2012-2015 and, therefore, data from three different cohorts of students was captured.

3.8.2.1 GCSE student participants

In total, data has been collected from nine schools, resulting in a sample of 661 students studying in years 10 and/or 11 participating in this study. These students were from different types of schools located in the region of West Midlands and from 0-4 categories of free school meal. These categories are based on the form of government benefit (e.g. income support, child tax credit) the parent of the child is entitled to, where students from category 4 can receive a larger pupil premium as their parents can gain more financial support than those students from category 0.

3.8.2.2 A level student participants

A level student data were collected from fifty eight different schools/colleges, resulting in a sample of 464 students studying in years 12 and/or 13 participating in this research. Of this sample, data from 207 students was collected from eight schools/colleges and the remaining sample of 257 students was collected by attending six different events.

3.8.2.3 First year STEM undergraduate student participants

In total a sample of 1280 first year STEM undergraduate students participated in this research. For this, data were collected over time from three different cohorts;

2012/2013, 2013/2014 and 2014/2015, and those who participated were studying engineering (965 students), mathematics (140 students) and computing (175 students) related degrees at two different universities. Of this sample, the engineering students were studying courses such as mechanical engineering and automotive engineering. For those studying a mathematics degree, the sample consisted of students studying courses such as mathematics, mathematics and statistics or applied mathematics and theoretical physics; whereas for the sample studying computing degrees, it involved students studying courses such as computer science and business information technology.

3.8.3 Quantitative data analysis technique

Student data were collected through a paper-based questionnaire. The reponses were first manually inputted onto Microsoft Excel where for each student group, a separate spreadsheet was created. Once the files had been tidied and checked for errors, they were imported into Statistical Package for the Social Sciences (SPSS).

An example of the type of questions which needed tidying was “if taken part in STEM outreach, which school year(s) was this in?”. In many instances, students gave a calendar year for example “2014” rather than their actual school year. For those students, the responses were coded as missing as it was difficult to make an assumption on which school year this was in. Usually, students after completing their GCSEs spend at least two years studying their post-16 subjects, but in many cases, it can be more, so making it difficult to speculate on the correct response.

The software package SPSS facilitated forming descriptive and inferential statistical analysis of the quantitative data collected from the student questionnaires, through which reliable and significant conclusions were drawn (Field 2013). Further checks on the accuracy of the data were made as on SPSS the variable type and the measurement of variables are set to default settings. In addition, due to the data entry for many of the variables being numerically coded on Microsoft Excel, labels were assigned to explain what each code represented on SPSS. For instance, gender was allocated with two numerical values; zero and one, where zero represented males and one represented females, and so on SPSS the variable gender was defined accordingly. Thus, to support the analysis stage, this approach was applied to all variables which were originally numerically coded on Microsoft Excel. Subsequently, whether a variable was numeric or string was also stated. This meant by defining the type of variable it would notify SPSS if the value inputted should be numeric or text, as a numeric variable would not allow any text to be written.

In addition, on Microsoft Excel, those students who did not provide a response to a question were assigned with a ‘.’ enabling data to be easily coded as missing on SPSS. Furthermore, the measurement of a variable can take the form of scale, nominal or ordinal, and this plays an important role in understanding the suitability of a statistical test (Field 2013). Hence, for all variables additional checks were made to ensure the assigned measurements were appropriate.

Thereafter, a descriptive analysis of the clean data were carried out to understand student participants’ basic features. Through this, an overview of the data and a detailed summary of the quantitative descriptions were captured. A separate inferential analysis followed using the sample of GCSE, A level and STEM undergraduate students, as this provided statistical insights on the sample of students involved in this study.

There are two types of tests which need to be considered: parametric and non-parametric, and the type of test chosen differs in accordance with the measurement of the dependent variable (Field 2013). For a parametric test, it assumes the data is continuous (scale), it follows a normal distribution, and the sample size is large and chosen at random. In order to perform a parametric test and, therefore, conduct Independent sample t-tests or Analysis of Variance tests, these criteria need to be satisfied. For non-parametric tests, the data is required to be nominal or ordinal, and for this type of data it is not necessary to check whether the data follows a normal distribution, and thus a normality assumption is not essential. A Mann-Whitney U test or Kruskal Wallis test are examples of non-parametric tests of which the sample is again usually large and randomly selected. In addition, types of parametric and non-parametric tests are comparable to one another and it is often suggested that dependent on the measurement of the variable an Independent sample t-test is equivalent to a Mann-Whitney U test (Field 2013).

Identifying the measurement of a dependent variable, and then the number of different values that are assigned to a categorical independent variable, validates which statistical test should be used. The student questionnaire data utilised two types of measurement dependent variables; nominal and ordinal (see GCSE, A level and STEM undergraduate student questionnaire). Thus, initially the type of questions used during the design stage can support the allocation of the measurement dependent variable. For example, nominal data tends to be derived from questions which quantify information, category or list or multiple choice question types; whereas questions that provide scale or ranking responses tend to produce data which are ordinal.

Therefore, the data for this study considered different types of non-parametric tests to investigate and outline statistical relationships from the student data sets. These include Mann-Whitney U test and Kruskal Wallis test (Robson 2002).

This research has used other statistical tests including chi-squared tests and Fisher's exact test. A binary logistic regression analysis has also been conducted and for this the Wald statistic value is presented when testing for the significance of individual coefficients displayed in the regression model.

For each statistical test, there are null and alternative hypotheses which are tested at a chosen significance level. If the probability (p-value) is less than or equal to the significance level, the null hypothesis is rejected and therefore, the results are significant at that level. For this sample, three significant levels have been considered; 5% (0.05), 1% (0.01) and 0.1% (0.001). The statistical output for all tests display the p-values and thus a star (*) has been assigned to those which were statistically significant at each level. Table 3.5 displays the key used to identify when the output was statistically significant at each level. Also if the p-value ranged between 5% and 10%, then the results were considered to be marginally significant.

< 0.05 significance level	*
≤ 0.01 significance level	**
≤ 0.001 significance level	***

Table 3.5: 5%, 1% and 0.1% significance level

This study used various types of rating questions of which the most common was a four-point Likert scale *("not at all, a little, quite a bit and very much")* (see Appendices D, E and F for a copy of the questionnaires). The responses were coded from a one to a four, where "not at all" was assigned a one and a four to those who responded with "very much". This scale was used in this study to explore:

- The level of awareness and knowledge gained about STEM related subjects after taking part in STEM activities
- The level of influence made towards their decision of further studying STEM related subjects after taking part in STEM activities
- On the whole, the level of understanding a student displayed on what each STEM related subject entailed

This technique of coding the responses has been applied to all ordinal questions and so for this, a Mann-Whitney U test or Kruskal Wallis test was used. The decision of which test was used depended on the number of different values that were assigned to the corresponding categorical independent variables. For example, as gender has two; when testing for differences in the medians of males and females, a Mann-Whitney U test was used. This was the same for whether or not the students had participated in extra-curricular activities, as the response for this variable was either a "yes" or a "no". For an independent variable which had more than two different values assigned, such as ethnicity, a Kruskal Wallis test was used.

In addition, a chi-squared test explored whether there were associations between dependent and independent variables that were categorical. For this, the data for each variable is nominal and the level of responses per independent variable does not matter. However, one of the requirements for using a chi-squared test is to have expected counts of at least five, so that the number of sample observations in each level of the variable is five or more. In addition, all cells in a contingency table should have an expected count of one or more. For valid results, these condition needs to be satisfied for at least 80% of the cells. However, if the sample size is fairly small and therefore, the expected count is less than five for more than 20% of the cells, a different test statistic would seem more appropriate; such as the Fisher's exact test. This test also explores the relationship between two nominal variables but takes sample size of small data sets into consideration (Robson 2002).

During this process, percentages have been reported so that consistency in interpreting the data is maintained and findings are shown in proportion to the number of students involved in this study.

3.9 Validity and reliability

Validity and reliability are important aspects of any research. Validity refers to ensuring this study is significant and of value, and reliability reflects on the dependability of the data and results (Bryman 2012). They play an important role in quantitative and qualitative research and thus for each the validity and reliability have been discussed.

Quantitative research

Validity - This focuses on the accuracy of the data and to what extent the instrument measures the intended factor (Oppenheim, 1992). Punch (2005) states three main approaches to validating the measurement instrument; content validity, criterion-related validity and construct validity.

Reliability - This focuses on the consistency of the data and to what extent the findings are replicable (Golafshani 2003). Bryman (2012) refers to three types of reliability: stability, internal reliability and inter-observer consistency.

Qualitative research

Validity - This focuses on the “representation of the actors, the purposes of the research and appropriateness of the processes involved”. In addition, Winter (2000); Cohen, Manion and Morrison (2011) suggest through “honesty, depth, richness and scope of the data achieved” validity can be verified and therefore put emphasis on the analysis technique.

Reliability - This focuses on the consistency of the findings in relation to the level of contact between the interviewer and interviewee (Krefting 1991), as well as mutual agreements during the analysis stage (Creswell and Plano Clark 2011). Denzil and Lincoln (1994) suggest three types of reliability: stability of observations, parallel forms and inter-rater reliability.

For the purpose of this study, validity and reliability of the quantitative and qualitative data and findings were verified through “collecting information from a variety of sources and with a variety of techniques” (Zohrabi 2013). Involving various stakeholders in STEM outreach (practitioners, teachers and students aged 14-19) provided a deeper understanding of their relationship as well as the impact of STEM outreach activities and provision. Merriam (1998) identified these methods as triangulation and participatory or collaborative modes of research.

In order to ensure there was validity and reliability in the qualitative data, great attention was taken during the analysis and interpretation stage, as they were in-depth face-to-face interviews conducted with teachers and practitioners in STEM outreach. Also, the validity and reliability of the questionnaires was obtained as quantitative data were captured from a large sample size of 2405 students studying for their GCSEs, A levels or a STEM undergraduate degree.

3.9.1 Limitations of the study

The willingness to be interviewed by the participating teachers perhaps indicates a higher than normal level of commitment. As a result, the findings from the teacher sample may be skewed as their interest may have influenced their involvement with the delivery and coordination of STEM outreach events.

A further limitation with using one of the main data collection tools in qualitative research is the use of language. The conversation held between the interviewer and interviewee is of essence the crucial part of the process of face-to-face interviews, though the way the questions and responses are interpreted can play an important role towards gaining a true representation of what is being investigated (Punch 2005). Alongside questioning the bias of this method, the length of time spent on an interview can be excessive. Hence, although this is a flexible approach to exploring new meanings of the "lived experience", the time-consuming element of this method is acknowledged (Creswell 2007).

Another key aspect taken into consideration was social desirability bias, as this study questioned participants on topics around attitude, influences, behaviour and understanding. Gathering data through paper-based questionnaires and face-to-face interviews meant it was difficult to obtain a response that reduced social desirability bias. Due to the possibility of the impact made by the presence of the researcher, the likelihood of initiating "answers that portray them in a positive light rather than reflect the truth" was high (Flanagan 2005: 44). However, this was addressed by the researcher trying to help teachers and practitioners feel comfortable and rather providing them the opportunity through stimulating conversations to verbally discuss and provide responses on a range of topics of interest. In order to encourage students to report the truth, they were presented with some questions that noted on the side "please be honest" and also were reassured about not being judged whilst responding to the questions, and that their results were not going to be shared without protecting their identity.

In addition, the quantitative data instrument involved students reading a project information sheet (see Appendix C), which described the research in detail and explained the information the questionnaire intended to collect. Students were asked to provide a yes or a no response to whether or not they had previously experienced STEM activities and further connecting questions were asked to those that said "yes". The purpose of this was to gain a deeper insight into their overall experience of the type of outreach they had been involved with and the impact it had made towards their understanding of STEM subjects and careers.

However, if a student had responded with a "no" they were able to avoid answering the connecting STEM outreach questions and asked to progress to complete the remaining mandatory questions. As a consequence, the researcher was concerned about a high proportion of students selecting "no" as their response. This was a concern as a pool of students would have been excluded from the exploration of understanding student experience and impact of STEM outreach. Since participating in this study was voluntary, it was expected that students would provide a true response when it came to answering this question. There was also a possibility that undergraduate students, in particular, may have forgotten their involvement in STEM outreach events. Therefore students were encouraged to think and write about their previous extra-curricular activities relating to STEM subjects whilst completing the questionnaires. Furthermore, the researcher acknowledged that, even if there was a reduction in the sample providing an accurate response, the sample that responded with a "yes" would have provided reliable and valuable information. This was highly appreciated as this meant some students have actively been involved with STEM outreach and most importantly remembered and shared their experience by the means of this questionnaire; thus, supporting the creation of a reliable data set.

3.10 Ethics

This research has followed the professional code of practice highlighted by the British Educational Research Association (BERA) Ethical Guidelines for Educational Research (BERA 2011). It has also followed Coventry University's ethical guidelines and gained ethical approval before conducting this research.

Great attention and care have been taken when dealing with ethically related matters during this research. When administering the questionnaires, GCSE, A level and STEM undergraduate students were provided with a project information sheet detailing a background brief of the research. This was followed by a consent form which asked the students for their permission to participate in this study. Through this, they were made aware that their contribution was voluntary and that they could withdraw their responses at any stage of the project. Any potential concerns that could have been encountered were addressed on the project and consent form to avoid any type of misunderstanding (see Appendix C for a copy of the project information and participant consent form). In addition, for those students who were studying their GCSEs and A levels, teacher consent was obtained via email prior to receiving individual student consent. A Disclosure and Barring Service (DBS) check was also conducted and this was presented at each school before data from this group of students was collected. This procedure was essential, as much of the data were collected from people who were under 18.

In addition, before the start of the interviews, oral and/or written permission was obtained from the interviewees (teachers and practitioners in STEM outreach) to record the interviews (see Appendix C for a copy of the project information and participant consent form). They were informed of their participation being voluntary and were reassured about the confidentiality of their responses throughout this study.

Careful consideration was also given towards protecting the participants' identity. This was maintained by keeping personal information such as the name of their school/workplace anonymous and by assigning each student, teacher and practitioner involved in this study a code, for instance 'student 1', and so their personal details were protected.

3.11 Summary

This chapter discusses in detail the relationship of participants involved in STEM outreach. A detailed explanation of the rationale for choosing a mixed methods research approach and the research questions are provided. It also discusses the method of developing the tools used to collect quantitative and qualitative data from three different age groups of students, STEM outreach coordinating teachers and STEM outreach practitioners. Furthermore, the use of SPSS as a statistical package and phenomenology thematic analysis are detailed. The limitations as well as ethical issues related to this research are also highlighted.

Chapter 4

Insights from STEM Outreach Practitioners

4.1 Introduction

This chapter details the analysis of data gathered from practitioners and discusses the qualitative results from semi-structured interviews with academic professionals from various Higher Education Institutions and organisations involved in providing STEM outreach activities (see Appendix A for a copy of the interview template for practitioners). As reported in Chapter 3, STEM outreach practitioners seek to enhance and enrich students' learning experience and expose them to areas of STEM that they may not be taught at school (see Figure 3.1) (Brawley et al. 2008). Through their interaction, they can inspire, intrigue and motivate students to study STEM subjects beyond their compulsory schooling and provide guidance on the possibilities of careers that are available with a STEM qualification (Turner et al. 2007).

The key factors that support and motivate STEM outreach practitioners to get involved in outreach are their passion and interest for the subject and their commitment towards sharing and educating young people about the benefits of STEM subjects and careers. Their enthusiasm allows them to express the range of opportunities available from STEM such that they want to reach out to others and make a positive difference (Bultitude and Rivett 2012). Several providers have very different agendas for their involvement in STEM outreach. For example, academic professionals may interact with younger students to help improve transition and support their university recruitment process whereas business organisations may engage with young people to support their corporate social responsibility and raise career awareness (CIPD 2012). Ultimately, all STEM outreach practitioners invest their time and money to aid development of talented STEM graduates and attempt to have a direct influence on the future of STEM workforce.

The key messages emerging from the practitioner data analysis are summarised by theme, proposing to answer RQ 1 presented in section 3.5, namely:

RQ 1) What are practitioners' perspectives on student access and target year groups chosen for STEM outreach, the methodology of evaluation of outreach activities and its impact on students' views and understanding of STEM subjects?

Practitioners' views on student access to STEM outreach are explored, providing a detailed exploration of the opportunities given to students to participate and engage in various outreach sessions. There is also a focus on practitioners' perceptions of the impact and evaluation of STEM outreach regarding students from the different socio-economic backgrounds, gender and ethnicity, and comparisons and evaluation of their experiences of observing and participating in various types of outreach activities. Their views are also detailed on the factors that influence the selection of year group to participate in STEM outreach, strategies to enhance the evaluation process and provide teachers with CPD opportunities. Furthermore, key interventions that can support practitioners in their role as a provider to motivate and enrich students' STEM skills and career awareness successfully are highlighted and barriers to providing effective outreach are detailed. Finally, practitioners outline their key qualities and reflect on key strategies to deliver effective STEM outreach activities.

4.2 STEM outreach practitioner sample

Within this sample, there were sixteen STEM outreach practitioners who specialised in a range of subjects including engineering, mathematics, computer science, chemistry and physics. Their roles as outreach providers varied across the sample outlining the diversity of those interviewed for this research. A summary of the practitioner data is presented in Table 4.1.

Practitioner	**Specialist Subject**	**Types of Organisation**	**Role title**
1	Engineering	Professional Body A	• Club Manager
2	Engineering	Professional Body A	• Team Leader
3	Engineering	Professional Body A	• Volunteer Engineer Tutor
4	Engineering	Professional Body B	• Education Coordinator
5	Engineering	Higher Education Institution A	• Academic
6	Mathematics	Higher Education Institution B	• Academic
7	Mathematics	Professional Body C	• Director of the Organisation
8	Mathematics	Professional Body D	• Outreach Coordinator
9	Mathematics	Higher Education Institution C	• Outreach Manager
10	Computer Science	Higher Education Institution D	• Academic
11	Computer Science	Higher Education Institution E	• Outreach Fellow
12	Chemistry	Higher Education Institution F	• Laboratory Manager
13	Chemistry	Higher Education Institution G	• Director of Outreach and School Teacher Fellow
14	Chemistry	Higher Education Institution H	• Director of Outreach and School Teacher Fellow
15	Physics	Higher Education Institution I	• Academic
16	Physics	Professional Body E	• Senior Operations Coordinator

Table 4.1: An overview of the practitioner data sample

4.3 Access to STEM outreach

STEM outreach practitioners, who engage and communicate with students, can share their passion towards a subject and demonstrate the benefits of studying further STEM subjects and careers (Laursen et al. 2007). Their approaches to providing access for students to participate in STEM outreach activities are detailed below.

Overall, they reported that students' access to STEM outreach activities was usually decided by the teachers. Teachers' knowledge of their students was the reason the selection process was normally left entirely to teachers. One practitioner stated:

"…we've got to trust the teachers. They're a professional; they have the expertise to choose who might benefit most, and I think by and large the teachers do choose students to come who will benefit the most from this activity, no matter what level they're at, and that's often what we see. So they might not bring every student, and they might not bring every gifted and talented or every special need, but they're bringing students who they know will benefit the most from the activity".

Practitioner 14

Practitioners 1, 6 and 9 supported this view and outlined how students' academic ability was not always the key reason for their selection. They found teachers often selected students with practical skills, and those interested and willing to take part, even during the weekends. On this theme, one of the practitioners pointed out that:

"Ok, the process that we use as the [Name of organisation] is we leave the selection entirely up to the school… they'll pick the brighter ones, but the brighter ones that are interested and engaged, not necessarily at the top of the class but the ones that are prepared to come on a Saturday morning to do some math".

Practitioner 6

Many practitioners detailed that their role during the selection process was usually to set general criteria, one being the number of spaces available to attend the outreach event. Hence, due to the limited number of spaces, the teachers were made to choose who to take as they cannot let everyone come to an event that only offers a fixed number of spaces. However, Practitioner 13 showed a lack of trust towards the teachers' decisions as he stated:

"So I will generally say, 'Can you identify students who have a genuine interest in science and maybe the aptitude to go on and study it in the future?', rather than just bringing along, you know, the bottom-set kids who – I've got no problem with the bottom-set kids but, you know, they – I don't want the teachers to think, 'Oh, this is a good way of getting these kids out of school for an afternoon, so let's stick them on a minibus and let X University deal with the problem'. I think it's important to get it right. So, yeah, it's a difficult one. Again, if we were running more – we had more places available, we'd just say, 'Bring everyone'".

Practitioner 13

Whereas, Practitioner 15 detailed his personal experience and described how strongly he felt about the gifted and talented scheme:

"It's incredibly divisive and is really you know the message you're sending out to the other kids… you're telling them you're not one of the gifted and talented… So I've no time at all for gifted and talented schemes, I would prefer if numbers are limited… and organised randomly, for me that's better because I get a wider range as well".

Practitioner 15

Practitioner 15 also wanted outreach to be generally available and stated:

"…they were only putting the better students through… I just want the students that are at the school to come; I don't want them filtered in terms of ability".

Practitioner 15

Practitioner 3 conveyed a similar message to Practitioner 15, as he would have preferred to have students that were of mixed ability and, rather than having the teacher involved in the selection process, allowing students to self-select instead.

Macdonald (2014) reported the effects of sending the wrong message to those who are not selected for outreach. She explained how activities can reinforce the idea amongst those students not selected that STEM is for the elite and not open to others. Hence, not being chosen even at a young age can be demotivating and discouraging towards further considering STEM subjects and careers.

Practitioner 11 had a slightly different approach suggesting that the nature of the outreach event should influence which students are selected to participate:

"It depends on what you're trying to do. I can see why – for the Creative Coding thing, they've chosen the top set, and for that, yes, the kids need to get up to speed really quickly; they need to see this project through for the whole year; they need to be the driving force behind it. That clearly needs the top set. But if it's the – if you're just doing a general, 'guys, STEM exists, you know!' thing… I want the bottom sets. The top set knows that".

Practitioner 11

For many outreach activities, due to the limited number of places, selection of participants has to take place and this task inevitably falls to teachers. There is a range of views amongst the practitioners about whether this selection is always as effective as it might be. Some are happy to accept the teachers' professional judgement whilst others have suspicions that sometimes outreach events are used as a way to have a short break from problem students.

Some selection is not of teachers' choosing for example the gifted and talented scheme. Some practitioners expressed frustration with this saying they wanted mixed ability students. Interestingly, a perception of some teachers which will be discussed later is that university practitioners are only interested in bright students (see section 5.3).

The approach set out by Practitioner 11 of making selection based on the nature of the outreach event and its objectives has much to commend it. For such good practice to take place it is essential that there is good communication beforehand between the practitioner and teacher so that both are clear on the nature and expectations of the event.

4.4 Year groups chosen to participate in STEM outreach

The practitioners were asked about the target year group(s) they considered was the most appropriate and effective for students participating in STEM outreach. The majority of the practitioners based their response around the purpose of the activity. Figure 4.1 summarises the rationales for choosing specific year groups.

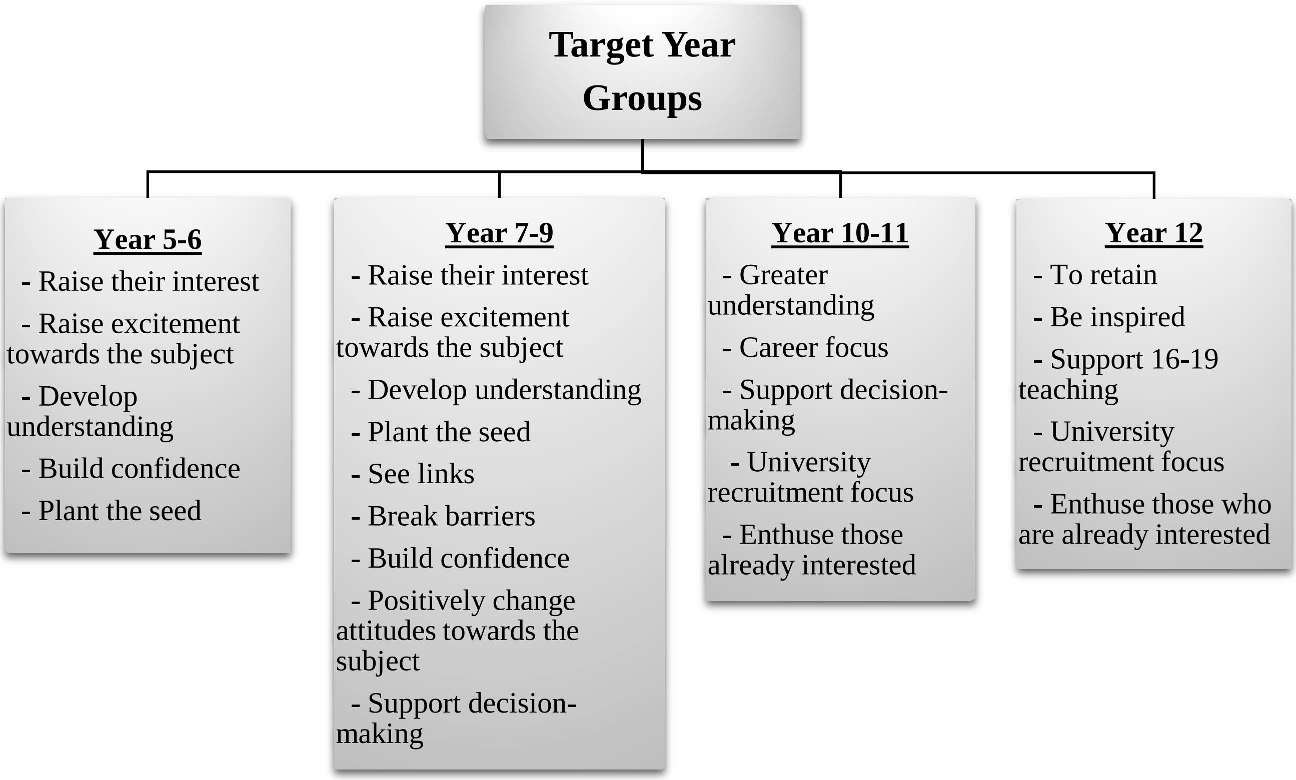

Figure 4.1: Target year groups to participate in STEM outreach

The message from all the practitioners interviewed was that outreach activities should be introduced to students at the latest by year 7, with provision continuing throughout secondary schooling. Half the practitioners gave reasons why it would be valuable to provide access to STEM outreach to primary school pupils and almost all of them spoke about introducing activities prior to the point that students choose their GCSE options. A few also described why it would be useful to involve students in outreach activities during the later school years. Overall, each transition period was identified as an important stage in which to influence students' study and career choices by targeting for involvement in STEM outreach. For example:

"I think in a sense some of the best ages are the transitional ages so year 6, year 7 as they are going up to high school, that's a very powerful age to work with kids, at the point they are making their GCSE options, although they are going to take maths, you know it, giving them the confidence and the drive to take the separate sciences which then sets them up so much better for doing A levels… so it's top end of primary, something in Key Stage *3, something in* Key Stage *4 and just building on each level as you go along… I think, whatever age you aim at you are going to have a limited effect if you just reach them once, where we think we get more impact is when you get a more sustained approach".*

Practitioner 9

Another practitioner detailed the importance of ensuring students had a succession of STEM outreach experiences:

"I think it works at every level, I think from year 4 and younger they will get really excited by it, they will love it whether it will change their lives or they will have forgotten it by tomorrow, but I mean by any age group if it's not reinforced might have forgotten it by tomorrow but the disillusionment with maths and the fear of maths begin to kick in when a child is 9, 10, 11 and it might be strongly embedded by the time they start secondary school, so those early secondary years are where you might be able to make a big difference in getting them back on track".

Practitioner 7

The importance of providing students access to STEM outreach in their early school years, especially to support their decision-making process, was reported by Practitioner 3:

"I think young – anything is much more effective if you target them young. Because that means they have the tools earlier in life… the earlier you target them, the more information they have to make decisions on their careers".

Practitioner 3

Another practitioner also preferred capturing the imagination of students with STEM outreach experiences prior to starting secondary school well before decisions about their futures were made:

"I think the best way of teaching or getting children to be interested in engineering is to show them at an early age before all the hormones coursing through them, so do it at primary… I wanted to encourage children at school age to become engineers and I felt that by the age of 15 children have made up their minds on what they're going to do".

Practitioner 1

A sense of frustration was portrayed by a few of the practitioners as they shared their experiences about the difference between interacting with older and younger students. They found a lower level of engagement and encountered other difficulties when interacting with older students. In comparison, the younger pupils were much more responsive towards the learning that took place during the session:

"If you… ask a volunteer to come down to the front and get involved in an experiment, like the whole 250 of them will put their hand up, 'cause they all want to do it. Whereas all the older, like, teenagers, you know, you can be pouring liquid nitrogen right next to them and they're just like… don't care. 'Don't ask me!' They don't want to".

Practitioner 12

Another practitioner described a similar experience and highlighted the level of curiosity the young children bring with them:

"That is another factor of kids getting older they get more self-conscious so you don't get that when you do a primary school workshop, I need a volunteer and 30 hands go up, you know you do the GCSE revision show, and you go what's this answer and you can wait 20-30 seconds and somebody will mumble it in the back corner".

Practitioner 9

Although targeting them whilst they were young was a response that was commonly shared, reasons to engage with the older students were also conveyed. For instance:

"So, yeah, I think getting a positive start in Year 7 and then, – if they've chosen to do chemistry at A level, some, you know, positive experiences in Year 12, so they don't all decide they want to do pharmacy".

Practitioner 12

The practitioners agreed that outreach events needed to have different purposes at different stages of students' schooling. It is important to start early (ideally in primary school) and raise interest and generate excitement. Later on, the focus needs to switch to career and further study decisions.

Many practitioners reported the different engagement levels between the enthusiastic participations of primary students and the apparent disinterest and apathy *("it's like pulling teeth", Practitioner 9)* of teenage students. Several suggested this change was due to physiological change such as puberty and social effects such as increased peer pressure.

Since this point was raised frequently, it suggests it is an area where sharing of good practice between practitioners is important to raise the overall effectiveness of outreach activities. It may also be another area where dialogue between teachers and practitioners could be beneficial since teachers have to deal with these issues on a daily basis.

4.5 Intended effects on students of STEM outreach

The practitioners also detailed their rationale for providing opportunities for students to participate in STEM outreach. According to the practitioners the benefits to the students are:

- Eye-opening experience
- Skills developed
- Raise confidence
- Increase motivation
- Change attitudes
- Career awareness
- Enriches learning
- Treated differently
- Correct misconceptions
- Raise aspirations

A key purpose highlighted by several practitioners was generating enthusiasm:

"I think the ultimate point is that we are ridiculously enthusiastic and excited about the subject, and we want to share that enthusiasm with the general public, with school students, with teachers".

Practitioner 14

The intention is for the enthusiasm to become contagious:

"…if you enthuse one or two they will hopefully enthuse others".

Practitioner 15

The importance of enthusiasm was echoed by Practitioner 11:

"*I'm just trying to get people enthusiastic and, if it's something they've never encountered before, show them that it's not as complicated as they thought. If it's a schools audience, and especially if it's primary school, then I'm trying to convince them that they can be scientists if they want to; that it's not – they probably even by sort of age eight or so are starting to think – in fact, certainly, they're starting to think science is for clever boffins, and probably also for boys, unfortunately. And so it's trying to break down those kind of ideas, for me. If it's a schools audience, that's the real main thing – trying to make – trying to include all of them".*

Practitioner 11

In addition to generating enthusiasm, she also wanted to raise aspirations and correct misconceptions, particular in relation to science being mainly for clever boys.

Another practitioner also focused on correcting misconceptions, although perhaps in a more paternalistic way:

"I know a lot; you know a little; therefore, I shall descend on you with my knowledge. There's a little bit of that in the kind of thing I do because I think for me it's about being able to correct misconceptions".

Practitioner 10

Connected to correcting misconceptions, other practitioners highlighted the need to provide information so that students can make informed decisions:

"Personally, well it's trying to pass on some information I suppose to the next generation and help you know I see my job as helping people to make their own choices so to speak. So yeah it's not perhaps telling someone you should do Physics, you should do Chemistry, go and be a doctor, go and be this, that and the other you know it's making them realise for themselves what opportunities there are and it may be Science it may be another walk of life entirely which is fine. But I think that's the most important

thing is making them aware of what's out there and they can make their own choices themselves".

Practitioner 16

4.6 The use of role models

The BG Group's STEM Education Learning report (2013) detailed the usefulness of role models in positively developing students' awareness of, and enthusiasm for, STEM subjects and careers.

Many of the practitioners in this study endorsed the need for appropriate role models. They were aware that who they were as individuals could often prevent them from being appropriate role models:

"It's all very well me saying, 'yeah, chemistry is a subject for women', but, you know, I'm a bloke who looks like a scientist saying it, so you need to – I think you need to put the right role models out there".

Practitioner 13

Practitioner 13 recognised that, as a male, there was only so far he could go in being a convincing advocate of the argument that females should choose to study chemistry.

Practitioner 10 took this viewpoint on into other characteristics beyond gender:

"So I genuinely think one of the things that I give them is humanity to it and a role model. In a way, I really get annoyed that I'm white, middle class and old, actually, and that really does – it genuinely does annoy me, because I know the power of role models – ethnic role models".

Practitioner 10

Clearly outreach practitioners cannot change their gender, age, socio-economic background or ethnicity. So, in order to address this issue many practitioners (from universities) involve some of their own students (undergraduate, postgraduates and even post-doctoral fellows) in outreach activities. This presents the participants in the outreach event with a range of people, with different demographic characteristics, making it more likely that there will be someone that the school students can identify with and view as a role model.

In addition to practitioners based in universities, many STEM outreach events use people from industry such as STEMNET ambassadors. Such ambassadors are able to give school students a first-hand account of working in a STEM career. As there is a large pool of potential ambassadors this can be another source of appropriate role models.

Outreach practitioners involve their own students for other reasons too. In particular where laboratory experiments are taking place, but in other interactive activities too, there is a need for several people to be involved in delivering the event (for example, acting as demonstrators). For practitioners working in universities, their own students are an obvious source of such 'helpers'.

Involving university students in STEM outreach is asking them to take on a role they have not undertaken before. Likewise, STEM professionals working in industry may not have taught in a school environment before giving their first presentation and so are venturing into a new sphere. It is therefore sensible to ask how they are equipped for this role and what training is made available to them.

4.7 Training for student helpers and volunteers

Some practitioners have developed extensive training programmes for their students. Practitioner 6 and Practitioner 12 talked at some length about what they offered:

"I have put public engagement on the agenda now as a university course so if a student comes to [Name of the university] they can actually do a course in public engagement and they get degree credit and part of that involves helping at [a science fair], part of it

involves doing the master class, part of it involves going to the Big Bang all that sort of stuff, so I am producing hopefully the next generation of public communicators… all of the students that do my communicating maths course do the shows at the Sciences fairs or the Big Bang and I help them design those, act as their mentor through the whole process from initial idea through to delivery, through to evaluation".

Practitioner 6

"They [my students] have to make activities that are going to be suitable for the age range, which is very challenging… so I organise the outreach event, I organise the printing of the posters, I proofread all the resources, I watch them – I make them rehearse their presentation, you know, I make them write a script so that I can look at – you know, I give them feedback on their presentation and everything so, you know, they're really well-rehearsed before we let them out to do it in front of any students".

Practitioner 12

These practitioners are clearly taking training very seriously and have a wide range of measures in place to enable the student helpers to be effective in their role. Practitioner 6 involves teachers in the development of the skills of the student helpers:

"…the creative spark comes from the students, but the teachers act in a mentoring role to turn that creative spark into something that would actually work with kids on the ground".

Practitioner 6

This illustrates the value, not only of good dialogue between teachers and practitioners mentioned previously, but also of combined working and involving teachers in the outreach activity.

Not all the training that is provided is thoroughly thought through as that described above. Practitioner 4 described conferences organised to train STEM ambassadors:

"Ambassadors will come along to that conference and they will get lots and lots of information thrown at them, sometimes it's too much to absorb all that information in one day but because we're available… So it's about having that open dialogue so they know who they can get hold of if they need and although we can impart all of that information in one day, as an individual may not absorb it all so it's about them having those access points that they can get to".

Practitioner 4

Practitioner 4 highlights the limitations of the training, with *"too much information thrown at them"* and concludes that the main achievement of the conference is to give them a contact point in the central organisation, someone *"they can get hold of if they need"*. It appears that this training does little to develop the ambassadors' skills particularly in relation to presenting to school students. As is discussed in section 5.6, teachers have mixed opinions about the qualities of such ambassadors with some reporting that levels and styles of presentations can sometimes be totally inappropriate.

Clearly there are issues of time in that ambassadors are doing this work voluntarily and taking leave from their employment to attend the training conference and then to go into schools. This makes it important to maximise the effectiveness of the training provided.

It is not only with industry volunteers that there is a time constraint on training. One practitioner described how online manuals are used to provide training:

"So we try and lay out the style in our manuals in a way we know but the emphasis about hands-on is the key and I try to make sure the volunteers know you know keep an eye on the kids, see if any of them are standing back, do you want to have a go, talk to them in a different way, one on one as well as in a group".

Practitioner 16

This practitioner is more cautious in his use of language than Practitioner 12. Practitioner 12 confidently asserts, *"they're really well-rehearsed before we let them out in front of any students"* whilst Practitioner 16 says *"we try and lay out the style"* and *"I try to make sure the volunteers know [what to do]"*. It seems that this practitioner may have some doubts about the comprehensiveness of this training approach (for example, some volunteers may not read the manual beforehand).

It was also found that not all practitioners provide pre-event training:

"So the first couple of pitches you do are rubbish, but you've got, like, you know, 150 people coming through in the morning. You may be bad in the first couple of them, but by the end of the day you've rehearsed and then we can – you know, we get feedback and improve things and stuff".

Practitioner 10

This is on the job training and the practitioner is confident that by the end of a day of doing pitches [to attendees at a science fair] the students have improved and are, by then, well-rehearsed. He seems willing to accept that the first few pitches of the day will be *"rubbish"*. This is in stark contrast to Practitioner 12 who requires his helpers to be well-rehearsed before they are allowed into contact with students.

Practitioner 13 described how he came to an appreciation of the value of appropriate selection of volunteers, training and feedback:

"But one thing I did notice last year that was interesting: on a few of the events – a few of the Twilight events, when I was going around, there'd be students who were looking a bit disengaged and they didn't know what they were doing, and I tied it down to the fact that there were just a handful of the demonstrators that weren't doing a very good job, in that they were not very approachable and they were giving, like, one-word answers to questions… so I dealt with that this year. I – well, I made sure that I selected people who I knew were, you know, the right sort of people for the demonstrating, but I also briefed everyone yesterday and just said, 'You are the face of [Name of the university] chemistry here. You should be promoting positive messages'. I also said that there were some – not complaints, but some comments were made by some students, and it wasn't the students visiting from schools and colleges; it was when my own –

’cause I get my own foundation-year students to do the same practical, and some of them had said, ‘Oh, the demonstrators are a bit moody, aren’t they?’ Then I looked into it a bit more”.

Practitioner 13

Whilst it appears that this year’s event is likely to be more effective than the previous year’s, the improvement has come about through learning by mistakes and some fortuitous feedback. The lessons learnt here were not new and could perhaps have been avoided had there been better sharing of good practice amongst the outreach practitioner community.

This section has demonstrated that there are quite varied practices amongst outreach practitioners in terms of the amount of training provided to helpers and volunteers, ranging from extensive programmes counting for credit towards a degree, through to on-the-job improvement through to nothing at all. It has also shown that the quality of outreach events can be reduced if insufficient training is provided.

A study by WISE (2015) reinforced this message, quoting a female engineer from the Royal Academy of Engineering who reported that “…by allowing untrained and narrowly prepared speakers to address this key audience, it could be that these outreach programmes are doing more to discourage prospective engineers than to incite the intended excitement and interest” (Macdonald 2014: 25).

4.8 Approaches to evaluation

The importance of evaluating STEM outreach activities, as detailed by many authors (Moore 2011; RCUK 2011; Chatwin et al. 2012), is to understand and measure the impact of outreach practitioners’ direct engagement with students as well as with teachers. The feedback collected can support future development, enhance the service of delivering the outreach activities, suggest key improvements and guide STEM outreach practitioners about what activities are successful.

Many practitioners spoke about the limitations of event evaluation questionnaires. Questionnaires of this type are used widely and students are typically asked to complete them at the end of the session. No practitioner spoke in favour of such questionnaires but many had negative comments about them:

"Teachers have been very honest with us about what's worked, what hasn't worked, why it's worked, why it hasn't worked, what the impact is on their school in the long-term, and it's much more important, rich data than somebody filling something in who's rushing to get a coach back to school".

Practitioner 14

"You have to force the students to answer the questionnaires and so stop ten minutes before the end, and stand over them while they write, and then collect it in… and if you've got half your forms missing, then we don't get all our funding paid".

Practitioner 12

"One of the problems you have is that when, if you give a questionnaire out, you're wasting that precious time. You've got them into the university and then you're spending ten minutes where they're writing stuff into a survey".

Practitioner 13

It appears that most practitioners only use these questionnaires because they are forced to either to secure their funding or to avoid getting *"hammered"*.

Several practitioners commented on the value of qualitative responses (often questionnaires end with a free text question asking for students' views of the best and worst part of the activity or how it could be improved):

"The strongest and most useful things I think we've ever got, that have changed the way we do things are free-text comments. Kind of asking 'best bit/worst bit/what should we change?' in there".

Practitioner 10

"The qualitative comments are the most interesting to read and you learn the most from them too whereas quantitative feedback is great for projecting [graphs]".

Practitioner 13

Some practitioners described the difficulties inherent in evaluating this kind of activity:
"As soon as you start evaluating things and trying to make it systematic, people try and quantify it, and this isn't the kind of thing that you can quantify, unfortunately. I mean, it is, ultimately, about communication, and communication is a very subjective thing. What gets through to one kid or one group of kids won't get through to a different group of kids from a different school or a different background. Or a different age. So… it's quite difficult".

Practitioner 11

"I think checking if learning is taking place in terms of outreach is a difficult thing to do… if you spend so much time trying to monitor or trying to quantify what you're doing you turn something which should be exciting and interesting into a chore… but my argument is even if you do get those responses how valuable are they, are they really statistically robust… instead a type of informal chat is often and also with the students that are often so much more useful than the questionnaire because the questionnaires tend to be a tick box and what's very interesting is we get hammered here in terms of we don't have enough".

Practitioner 15

Whilst the difficulties of evaluation should not be underestimated, these responses (particularly when put alongside that of Practitioner 14 below) do appear limited. Practitioner 15 questions the statistical robustness of questionnaires but relies instead on *"an informed chat with students"*.

The response of Practitioner 14 in terms of evaluation was the most detailed:

"We've had much more fruitful feedback by having in-depth interviews and discussions with teachers over a longer period of time... and there, you know, it's very open, free

and frank… we want to know the truth – the real truth, and that comes out of a verbal discussion and in more in-depth interviews with people".

Practitioner 14

He went on to describe how this was not a one off conversation at the end of the event but an ongoing, longitudinal process:

"…critical feedback is the teacher. The teacher knows that class very well. They know very well whether that's been a good event, a bad event – how that, you know, has moved people on. And we've had some really good feedback from teachers over time. It's not a question of on the day. It's a question of engaging that teacher and they'll return. Because quite often we've had feedback from teachers six months down the line when they've said, 'You know, that event had a big impact on that student, because that student has now decided to do this', or, 'has now decided to do that', or, 'has been stimulated to do this'. That's the critical feedback. The longitudinal – the longer-term, process feedback that you really want".

Practitioner 14

The key role that teachers can play in evaluation was also emphasised by Practitioner 6:

"The hardest thing to judge is whether you're meeting your learning objectives and that's really hard and the best way to do that is to engage longer-term with the teachers, that's probably the hardest of all, have they really learnt something - no form of assessment - just speak to teachers".

Practitioner 6

Furthermore, the practitioners have frequently used phrases such as *"I think, trying and hope"*. Hence, it seems they do not refer to their own feedback but instead report an outcome they aim to achieve *("I'm trying to get people enthusiastic…"),* suggesting their intended outcome is not rigorously evidence based. The approach practitioners seem to be taking can be harmful as it is not necessary that what excites them; will in return excite students that are underrepresented in STEM. This mindset is perhaps questionable as it can overestimate what they actually can achieve to ‘what is achievable’.

The practitioner responses also give a feeling that they are less in touch with the reality and rather possess idealistic approaches. For instance, Practitioner 16 talks about providing students with key information to support their educational decisions. Although the students are being made aware so that they can make their own choices, the practitioner creates the impression that once he has given this information, this is it.

Once again, the importance of close dialogue between teachers and practitioners comes into force. This time the dialogue is needed after the activity rather than before. It is clear that the teachers have access to information that is not available on the day. Since the main purpose of STEM outreach is to achieve lasting impact rather than simply giving the students ‘a good time’ on the day, it seems clear that there is great value in the longer-term discussions with teachers undertaken by Practitioner 14 and Practitioner 6.

4.9 Teachers’ professional development from participating in STEM outreach

This study also focused on how the teachers’ involvement in STEM outreach impacted their continuous professional development. As the practitioners reflected on this question, they expressed their belief that the teachers benefited from their outreach experience. Some practitioners described how teachers were positively influenced by being involved in their students’ outreach experience and some detailed how teacher training courses were provided that further enhanced the teachers’ skills and knowledge. The practitioners also reported how enriching the knowledge and skills of teachers impacted students learning inside and outside the classroom and expressed a great level of importance towards the relationship that they formed with the teachers.

The findings suggested that practitioners believe teachers are greatly influenced by the opportunities that are provided to their students, as one practitioner explained:

"So when we were in the master classes, teachers come along to act as tutors, so when we've got the workshop materials we've got typically 100 kids and we break them up into groups and the teachers go with each group and facilitate, so they are also learning by doing the master class".

Practitioner 6

As well as providing indications for learning new knowledge, practitioners also outlined that simultaneously teachers were regaining and refreshing their knowledge and identifying how certain activities could be used and implemented in their classroom teaching:

"I think that the staff quite often will benefit from it and they'll see any activity or an approach to something and they'll say 'you know what I can use that'… yeah or they'll say 'we'll be following this up in class or whatever, that's something I can remember'".

Practitioner 9

He also suggested how primary school teachers often enjoyed and learnt from their experience, which would then be communicated to the students:

"The other good thing with an awful lot of primary school teachers is that they are willing to have a go, they are willing to have a go at something and give it a try and usually they'll enjoy themselves and again you get an emotional reaction out of the teachers, oh we quite enjoyed that, there's an hour gone already, that can be really positive because that will then reinforce that positive message back to the kids and they'll put their display up and they'll talk about it with the kids at the end of the week".

Practitioner 9

Another practitioner who also works very closely with primary and secondary school teachers detailed how teachers had been inspired and gained confidence through their involvement in STEM outreach activities. Acknowledging the importance of this, he further stated how currently a disparity between teachers' awareness and experience of practical experiments exists, such that engaging with them has supported and allowed the practitioners to be a key resource for the teachers:

"Often when they see these practicals and they see the kind of things, they look and go, 'I could do that.' And you think, 'Yes, you could do that'... but the culture of doing practical work is dropping and a lot of teachers just haven't had the experience. I mean, you do need to be shown something. You know, you're not going to just rock up to a lab and suddenly mix chemicals together irresponsibly. So you do need help and support and training, and somewhere in the sort of passing on of knowledge, there's a gap there, somewhere. So when they come here, the teachers see the kind of things that can be done and that inspires them and helps them and supports them, so they do find this is also a really important part of their training".

Practitioner 14

Practitioner 14 reported that, along with the outreach work he and his colleagues do; they provide professional training for teachers. In the past, they have also set up contemporary science conferences covering all three sciences, and as a team have written articles for school teachers, and through discussion and dialogue, involved them in the early stages of developing their STEM outreach programme.

Five other practitioners also described their interaction with teachers through teacher training courses and detailed the positive impact this has brought towards the teachers involved:

"What we do in the teacher training: we put the teachers in exactly the same position as if they were students… so we're trying to, again, upskill them because if we can get one teacher to hit 30 kids, that's obviously the way to do it".

Practitioner 8

These practitioners have conveyed an important message that the impact is a two way process: if the teachers benefit then so do the students, such that enriching one teacher can benefit thirty students. Practitioner 8 further detailed a comment that one teacher had written on his teacher feedback form and that was "*you have just restored my faith as to why I went into teaching!"* He explained comments such as this show how outreach can upskill the teachers and build their confidence and thus through the means of the teachers the students are supported too.

Another practitioner considered teacher development as a type of outreach:

"I would say upskilling the teachers is the best form of outreach. Giving them access to interesting and exciting, contemporary research information in a form where they can use it in their class because national curriculums and stuff tend to have been written a while back and get very stale… and, actually, upskilling the teachers, because those teachers will remain over a period of time whereas single interventions are very difficult to prove anything from. So we train the teachers".

Practitioner 10

Practitioners have described two kinds of professional development for teachers: upskilling courses for teachers and attending events aimed at school students. Practitioners view the former as a kind of outreach on the principle that the upskilled teachers become more effective at inspiring their students to choose STEM disciplines. Whilst this secondary effect is hard to achieve, there is clear evidence of attendees at these courses reporting increased levels of confidence.

The practitioners believe that the teachers who attend outreach activities with their students are also developed. Although events are aimed at enthusing and inspiring students, some teachers, particularly from primary, are also enthused. With secondary teachers the benefit may be more in terms of their ability with the subject; exposing them to some of the latest ideas in the subject can reinforce their view of themselves as scientists. However, whether this professional development leads to more students studying STEM and choosing STEM careers has not been evaluated by any of the practitioners.

As will be seen in section 5.8, the teachers views of the professional development they receive through participating in STEM outreach do not exactly concur with those expressed by the practitioners.

4.10 Support for providers to organise and provide effective STEM outreach

The practitioners interviewed during this study highlighted the type of support they considered they needed to ensure they were able to enhance their approach to delivery. The three factors that they identified were:

- Financial
- Time
- Administration

Financial support was viewed as an essential element to ensure students were provided with greater access to STEM outreach. A comment made by a practitioner was:

"It's all driven by economics so, you know, money. If money was no object, you know, I'd just do much more".

Practitioner 12

Similarly, another practitioner also reported how more outreach could be done if funding was available:

"So yeah the demand for it is really high which is great, it's just the case of finding more funders to get them on the road, if we had three on the road I'd be very certain we'd be able to tour nonstop".

Practitioner 16

Both practitioners expressed their desire for achieving a steady source of financial support. Some practitioners also felt STEM is not given a high priory within school, so less focus is given towards spending money on practical experiments and students involvement in STEM outreach events.

Three other practitioners mentioned resourcing issues, either gaining additional support from a university perspective or purely from an individual perspective. One practitioner, who was an employee at a university, described how time was a constraint as he was aware before his ideas were implemented to a wider audience, the activities required to be tested and amended appropriately, ensuring what he delivered to the students was effective and a valuable experience:

"I've got hundreds of ideas. It's just finding the time to make them a reality and I think as well you need to try them 2 or 3 times and have a little bit of failure before you get it".

Practitioner 5

A further comment that suggested administrative support would be beneficial was made:

"I would love to give them [the students] the opportunity but I've only got two arms and two legs".

Practitioner 3

These practitioners were asking for more money or time to do outreach activities. They did not mention 'working smarter'. Others have addressed being more efficient through the provision of admin and organisational support. Practitioner 14 was formally a school teacher but is now working as Director of Outreach and he reported how his role facilitates more academic staff involvement in outreach.

4.11 Teachers as a barrier to providing effective STEM outreach

Many practitioners detailed the importance of the relationship they have with a teacher. A comment made by Practitioner 9 explained why maintaining this relationship was crucial to the outreach provision:

"You know the relationship with individual teachers is very important because you know they're the gatekeepers, to have that relationship and that effect on the kids then you need to have that relationship working with the teachers and if you find that a particular teacher has been your link moves to another school, in the best situation they hand that link to somebody else and then set up a new link from the new school. But quite often you can get, you lose one or the other".

Practitioner 9

However, many practitioners highlighted how teachers are sometimes a barrier, negatively affecting the level of engagement that takes place with the students. The reasons practitioners identified as their key concerns were:

- Lack of interest and awareness from teachers, therefore, restricting students' access to outreach

- Teachers' preconceived views on student suitability to participate in outreach

- Teachers' intervention during students' outreach experience limiting their opportunity to answer and learn from the experience

- Teachers' difficulty in attending events off the school premises reducing students' access to STEM outreach activities

During the interviews practitioners commented about these key messages:

"I've had other instances of where we've been running an outreach event for Year 12 and we've, like, set up the glass-ware, and the teachers will be telling them it wrong... you do hear them telling them things wrong sometimes I think".

Practitioner 12

Practitioners shared experiences about how teachers may have preconceived views on students' abilities, but the students may prove the teacher wrong. Practitioners 2, 3, 9, 14 and 16 commented on how surprised teachers were by their students' interaction for example:

"I've gone into classes where I've been told, 'Student X is a "problem"', and I'm using inverted commas here, and I've found Student X to be the best student doing the practical… we are constantly amused and surprised at how much the students can do as are their teachers, when they're given the opportunity to do so".

Practitioner 14

Another statement that was expressed by the practitioner was the lack of awareness of the term STEM and organisations providing outreach activities:

"I still go into schools where teachers say 'STEMNET who are they and what's a STEM ambassador and what do they do?' And you think actually this programme has been around from the year 2000… and when teachers are saying they still don't know what the STEM ambassador programme is, it makes you think well we need to do something".

Practitioner 4

As noted, a number of practitioners' experience of certain students did not match up with the views teachers expressed to them before the activity. There could be many reasons for this mismatch. For example, the practitioners are only getting a one-off view of the student, whereas the teacher sees them regularly. Or the different nature of the outreach activity may have caught the student's attention in a way routine schooling does not. Whatever the reason, there is potential value in this being fed back to the teachers giving further evidence of the need for post-event dialogue between teachers and practitioners.

4.12 Key strategies to deliver effective and engaging STEM activities

The practitioners reflected on key strategies they considered impacted on the delivery of successful STEM activities. They outlined elements that they recognised were essential towards maximising a student's STEM outreach experience and further provided explanations on factors that they perceived made a difference towards effectively interacting and engaging with the students and teachers.

Many practitioners talked about the type of activity students engaged with. They emphasised the importance of activities being fun, interactive, simple to understand, relevant to students' everyday life and conveying a clear key message that students could take away after the event. Practitioner 9 described the importance of having that *"hook"* so that the students become more interested and curious to know more:

"That's where the themes come in, you know there's that aspect of why do I need to know this and you can say well you need to know this because you need to be able to do that… this is why this works, and you can sort of build on it just having that hook that will get them to say actually I do want to know about this'".

Practitioner 9

He explains how he finds using themes as a great way of formulating the questions and so allowing the students to see the relevance as it puts things in context and makes it a more interesting and memorable experience. The use of themes was also reported by Practitioner 5, with the approach of making the activities relevant to students' experience and examples of using popular iconographies such as Harry Potter, Star Trek and Alice in Wonderland.

Keeping the activities relatively simple as well as affordable was also seen as important, as well as allowing the students to make and see those connections:

"Keep it simple. Make sure that there're not too many processes in what you're trying to do. So if you've got an idea, don't try and make it excessively complicated because the child will try to overcome the complexity and not understand what they're doing. Keep it cheap, otherwise you'll never afford to do it".

Practitioner 3

Three practitioners emphasised involving the students in an interactive activity which was more than just a demonstration. They viewed this as a powerful approach and one practitioner identified this as an essential element towards making outreach an impactful experience:

"…you know you can get some very good public lectures and talks but I think in general the best things will have a strong interactive element where the kids are getting to actually do something themselves. It's like the origami, they go home with some things that they've folded themselves, they've actually had a go it's not just somebody demonstrating, I think a strong interactive element where the kids actually get to do maths rather than just see or hear maths I think that's a crucial element of any successful outreach".

Practitioner 9

Other practitioners detailed the importance of keeping the conversations brief, especially at the start of the activity. The recommendation was to keep the speaking to a minimum and move to the interactive aspects as early as possible, but to keep activities logically structured:

"One of the important things is the amount of talking that goes on at the beginning, keep it brief, to the point and just a minimum number of points. Get the kids active as soon as you can doing rather than listening".

Practitioner 2

Another practitioner described a similar approach:

"Talking the same amount but in smaller, more digestible chunks… so you have to talk a little bit, then do an activity, bring them back together and do another activity".

Practitioner 12

The importance of ensuring outreach is pitched appropriately is a critical factor. At the start of an activity key questions were asked by one practitioner to understand students' level of understanding:

"It can sometimes be helpful — say to the audience, 'so I'm going to be talking about this. Is everybody clear on this?'".

Practitioner 11

Similarly, another practitioner detailed how, dependent on the audience, you must be prepared to change your pitch accordingly:

"You have to learn to pitch it at different levels. That's tough, that's not easy, the easiest thing in the world is to just generate something, here's my 45 minutes and I put it across like this, but that doesn't work, that will fail most of the time because you have to be sensitive to what they know".

Practitioner 15

Like Practitioner 11, he asked key questions at the beginning of the sessions, allowing him to identify and gauge students' responses to determine how he tailored his style of pitching.

In summary, the key strategies identified in the delivery of effective STEM activities were:

- Activities should be fun, interactive, simple, affordable and relevant
- Attempt to get the students hooked
- Use themes to support students' engagement with the topic
- Let students go home with a clear message
- Keep dialogue with students minimal at the start of the activity
- Ensure the activities are pitched appropriately
- Prior to starting the activity, ask key questions to gauge students' responses
- Be cautious of a students' attention span and attempt to talk in small, digestible chunks

4.13 Key qualities of a STEM outreach provider

The practitioners identified certain qualities they considered were essential to support their role as a provider for delivering STEM outreach:

- Creativity
- Enthusiasm
- Commitment
- Good communication
- Ability to engage and enthuse students
- Willingness to give out free time
- Have a genuine interest in the subject
- Ability to break the concept down and explain the relevance
- Ability to approach the delivery from the child's point of view
- Have teaching experience to support the providers' understanding of student attributes
- Ability to provide independent, authentic and non-judgemental advice to students

For example:

"It's something as I say I really enjoy and very committed too… you can stand up and tell students the earth is flat and as long as you do it with enough enthusiasm you'll get a few that will take it on board. It's slightly facetious but honestly, I think it's a combination of you know a genuine interest and a genuine enthusiasm for the subject coupled with being receptive to what's going on and that's something that really takes a lot of experience".

Practitioner 15

Hence, being committed, creative and along with having a great level of enthusiasm and interest in the subject were amongst the many key attributes the practitioners detailed.

Sometimes outreach is delivered by individuals who do not have all (or even most) of these attributes:

"On a couple of occasions where one of my colleagues has gone out to give a talk in a school or college and they've pitched it too high or they've been a bit disorganised and it's not gone very well, or they weren't the most dynamic individual anyway and you probably didn't want them to go to a school but they volunteered so you said yes".

Practitioner 13

Whilst outreach remains a voluntary activity perhaps this kind of mishap will inevitably occur. It appears that Practitioner 13 did not want his colleague to deliver the outreach because he knew that his colleague did not have the right skills but nonetheless the colleague was allowed to go. Perhaps there was no alternative and certainly it could have been difficult for Practitioner 13 to tell his colleague he did not have the right skills; but the consequence was that students received a poor outreach experience.

There is evidence that universities are starting to recognise the need to have appropriately skilled individuals undertaking outreach. Some are doing this through employing former school teachers. Three of the practitioners in this study had a teaching background which they felt was a valuable asset.

Practitioner 13, after completing his post-doc, taught in a comprehensive 11-18 school for just under five years. During that time he developed a passion towards science communication and especially got involved in getting students that were not interested in science more interested. He started a 50% outreach role at a university and now is the Director of Outreach for Chemistry and considers new roles created in outreach with a requirement for some level of teaching experience will become increasingly common:

"So, as I'm doing a talk, I'm looking at the audience, and if they're getting bored, I can see that I'm doing it wrong and I need to change what I'm doing, and that's just – that's part of the nature of being a teacher, and you learn to interact with your audience and monitor them and scan them, and not all of your outreach colleagues at unis will do

that. Some of them just look at the back and not talk at them at all, and they wouldn't have any idea what's going on… I know people at various other universities where they have an outreach person who was a school teacher before. Yes, it makes a huge difference in terms of design and delivery and all the business about, you know the sort of subliminal evaluation that you're doing the whole time. They're just things you learn as a teacher… and I think now people who want to get into outreach are identifying that teaching experience is going to help them, so you might see more of that in the future".

Practitioner 13

Another practitioner shared a similar experience as he was a former secondary school teacher and now is a School Teacher Fellow and the Director of Outreach at a university. Having been in this role for the last ten years, he has promoted chemistry and supported teachers along with their students and this has increased year on year. He explained how the model they have, with the involvement of a School Teacher Fellow is what makes what they do sustainable and work exceptionally well. They are able to facilitate all types of outreach due to the increased numbers of PhD students they have in their department. He further described how his role supports teachers and other academic staff who may want to do deliver outreach but struggle with liaising with schools:

"And also [teachers] they've got a fixed point of contact. Too many of the outreach projects no doubt you've come across actually chop and change staff several times per year. And teachers don't like instability like that. And they also need to know that the staff who are actually dealing with their outreach requests, if you put it that way, are actually going to deliver something that is at least very good, if not excellent, time after time after time. It has to be reliable… if they're a member of staff who has a research grant that requires some impact and they're actually working directly with the outreach here in [Name of the university], we just simply call them or their post-docs in to give talks at a particular time, knowing which audience it is. They don't have to organise it; we've organised it for them. They'll just slot within the programme. And other members of staff are quite willing to go out into schools to give talks, providing it gets organised

for them, so they don't have to do the mundane stuff of making contact with the school. And our lot are actually in demand, rather than have to go looking for it".

Practitioner 14

Thus, key qualities of a STEM outreach provider have been presented, supporting the effectiveness of STEM outreach delivery and impact. These qualities identified by the practitioners define essential elements to form a valuable and unique experience for those involved in delivering STEM outreach.

4.14 Key points from analysis of practitioner data

There are several crucial points that emerge from the practitioner analysis:

a) In many areas there is considerable variation of practice between practitioners
b) In virtual all areas related to STEM outreach, high levels of interaction between practitioners and teachers can enhance the effectiveness of STEM outreach
c) Evaluation of STEM outreach is generally not as well developed as the activities that take place during outreach events
d) The need of sharing good practice amongst practitioners as a wide range of them have different agendas

4.14.1 Variability

The data presented and discussed throughout this chapter has clearly indicated massive variability in practice in most areas related to STEM outreach. The case of training for student helpers and other volunteers (such as ambassadors from industry) illustrates this very clearly.

At one extreme there are these practitioners who have developed extensive training programmes for their student helpers, to the extent that undergraduates can gain academic credit towards their degree by participating. In the middle are those who recognise that training is valuable but because of limited time and resource, end up offering training that they recognise as having limitations. Finally, there are those who offer little or no training initially and only introduce it to address identified failings in practice.

As part of the National HE STEM programme (2012), the Royal Academy of Engineering was involved in a project where they provided "bespoke training" to staff and university student STEM ambassadors. Through this training, they engaged with 450 students and 30 staff members, and they were all encouraged to replicate this training at their university with other individuals involved in the delivery of STEM outreach. The key outcome from this project was the development of inspiring STEM practitioners that could communicate effectively with young people.

Currently STEMNET, who run the STEM Ambassador Programme, offer four different types of training; Induction Training, Extensive Training, Powerful Practicals and People Like Me workshops. These training workshops are designed for different purposes and are for a range of STEM practitioners, tailored to support them with various aspects of delivering an effective STEM activity (www.stemnet.org.uk).

However, at present there is no formal training required for all such individuals, as there is no framework in place that states all STEM outreach practitioners must take a form of structured training prior to their engagement with young people. An intensive training programme has not yet been developed which identifies outreach practices based on quality.

4.14.2 Interaction between practitioners and teachers

It is obvious that both practitioners and teachers must play a role if STEM outreach is to take place. Without practitioners there are no activities for students to access; without teachers there are no students to access the activities. For outreach to be as effective as possible, there needs, at the very least, to be good communication between the two groups.

This communication is needed at all stages, before the event takes place (e.g. to discuss student selection, topics to be covered); during the event (e.g. to address levels of pitching) and after the event (particularly for evaluation). From the practitioner analysis presented here, and from the teacher analysis in Chapter 5, it can be seen that if the interaction can go beyond good communication to a real partnership the effectiveness of the outreach activities can be further improved.

Where teachers are clear and committed to the focus of an outreach activity, they can spend time in class before the event takes place to cover preparatory material to help students benefit most from the event. As teachers generally know their students well they can give valuable feedback throughout outreach sessions, allowing practitioners to modify what they are doing to give better outcomes. After the events, teachers can seek to consolidate learning outcomes from the outreach event.

Such a close working relationship may be ideal, but it seems that the reality is that in some cases there are tensions in the relationship. Some practitioners are suspicious of teachers' motives. For example, one suggested that teachers might view off-site outreach activities as a way of having an afternoon off from the most troublesome students. And, as well as shown in Chapter 5, there are suspicions the other way, with some teachers feeling that university practitioners are only interested in the brightest students.

At their worst, these tensions and suspicions may have a tendency to limit communication and can therefore create a vicious circle of less communication creating reduced understanding of the constraint the other party is working under, causing increased suspicion and tension. There is a need for both, practitioners and teachers to commit to high levels of communication to prevent the vicious circle from establishing itself.

4.14.3 Evaluation

The data presented and discussed in this chapter clearly indicated massive variability in evaluation strategies. Most of the practitioners felt that post-event questionnaires have limited value and they did not prefer quantifiable approaches of evaluation. In their opinion this provided a general feedback. They are often creative people with lots of ideas who want to be doing rather than evaluating (for example, one practitioner point to the danger of evaluation becoming *"a chore"*).

Social science research methodologies are needed for rigorous evaluation. This will be useful in order to understand the impact of outreach activities on students and teachers. This approach will also help the practitioners to understand the different types of learning behaviours of the students' e.g. cognitive learning and constructive learning. This is a different paradigm for STEM outreach practitioners and it may be helpful to draw on the expertise of others (possibly in some longitudinal studies like Practitioner 14).

Teachers have a valuable role to play in the evaluation process. Close dialogue between teachers and practitioners is important after the activity as teachers better understand the learning process of their students. The main purpose of STEM outreach is to achieve lasting impact therefore the longer-term discussions with teachers are extremely valuable. As a result qualitative responses provided better learning.

4.14.4 Sharing good practice

Due to variability in practice it is good for everyone to be aware what others are doing. The practice sharing should not only focus on specific activities or the characteristics of a good activity but on all aspects around an event like organisation, planning, training and evaluation. This will be helpful for those doing it for the first time.

Effective sharing of practice between the STEM outreach practitioners could be extremely useful in improving the evaluation methodologies and delivery. Thus, providing a cohesive and coordinated approach of STEM outreach for maximum impact. This will be helpful in addressing the shortage of future STEM workforce.

4.15 Summary

This chapter has presented an in-depth qualitative analysis of the findings from the semi-structured interviews with outreach practitioners involved in facilitating various STEM related outreach activities. As well as detailing the strategies the practitioners used for student access, the importance of using student role models that are trained is also discussed. Further, key factors that were found to influence the decision of choosing specific year groups to participate in STEM outreach are detailed. Their views on evaluation, teacher development and type of support needed are highlighted. Key strategies and qualities of a STEM outreach provider that were perceived to benefit and impact a student's and teacher's STEM outreach experience are listed.

Chapter 5

Insights from Teachers Involved in STEM Outreach

5.1 Introduction

This chapter details the teacher data analysis and discussion of qualitative results from the semi-structured interviews with secondary school/college teachers involved in facilitating STEM outreach activities (see Appendix B for a copy of the interview template for teachers). As reported in Chapter 3, teachers also take on a crucial role towards the provision and coordination of organising outreach events (see Figure 3.1) and their role as a facilitator can bring immense value and contribution towards the quantity and quality of experience students gain through outreach participation (Chatwin et al. 2012). Thus, this chapter focuses on and explores teachers' wealth of knowledge, views and experience to gain a deeper understanding of their role as a coordinator for organising STEM outreach activities from a school setting. The key messages emerging from the teacher data analysis are summarised by theme, proposing to answer RQ 2 presented in section 3.5, namely:

RQ 2) What are teachers' perspectives on student access and target year groups chosen for STEM outreach, the methodology of evaluation of outreach activities and its impact on students' views and understanding of STEM subjects?

Teachers' views are explored on student access to STEM outreach, providing a detailed outlook on the opportunities given to students to participate and engage in various outreach sessions. Their views on the factors that influence the selection of year group to participate in STEM outreach, enhance impact on students and strategies for effective evaluation process are also detailed. Finally, key interventions that can support teachers in their role as a facilitator to develop students' STEM skills and career awareness effectively are highlighted.

5.2 Teacher sample

Within this sample, there were teachers who specialised in a range of subjects including biology, chemistry, physics and mathematics, and details on their role as a facilitator varied across the sample. Of all the participants, Teacher 5 was a support teacher and Teacher 8a/8b represented two teachers from the same school, who came for the interview, and those that did not provide a response are labelled with a '-'. A summary of the teacher data is presented below in Table 5.1.

Teacher	**Specialist Subject**	**Free School Meal category**	**No. of Years of Teaching**	**School year they teach**	**Role title**
1	Biology	4	-	Years 7 - 13	• Head of Science
2	Biology	2	-	Years 7 - 13	• Associate Head Teacher • Gifted and talented education and enrichment
3	Biology	2	6 years	Years 7 - 13	• Acting Head of Science • STEM and Environmental club coordinator
4	Biology	4	-	Years 7 - 11	-
5	Biology	2	1 year	-	• Intervention manager in the science department • STEM organiser
6	Chemistry	3	23 years	Years 7 - 13	-
7	Chemistry	2	15 years	Years 7 - 13	• Associate Assistant Head Teacher • Advanced skills teacher
8a/8b	Physics	4	10 years	Years 7 - 13	-
9	Physics	3	7 years	Years 7 - 13	-
10	Physics	4	12 years	Years 7 - 13	• Lead practitioner
11	Mathematics	2	-	Years 7 - 13	• Head of Maths

Table 5.1: An overview of the teacher data sample

5.3 Access to STEM outreach

In this section, we explore the role of the STEM outreach facilitator (teacher) in selecting which students are invited to attend a specific STEM outreach event. For some events, there is a completely open invitation and the teacher does not need to choose; in these cases, the process is one of individual self-selection. In other cases, a limited number of places are available and a selection has to be made. Sometimes the STEM outreach practitioner organising/delivering the event may give guidelines (e.g. event is suitable for middle ability pupils) or regulations (e.g. attendees must be girls or receiving Free School Meals - such regulation may arise because of the funding source for the event). In other cases, there are no guidelines and the decision is entirely by the teachers.

Many teachers described how the decision of who was chosen to engage in STEM outreach primarily depended on the type of activity. For instance, activities that were organised by the STEM outreach practitioners (professional institutions, voluntary organisations and Higher Education Institutions) often provided guidelines that supported their decision-making process and rationale for choosing who to give access to outreach. In other instances, the teachers followed their own criteria, often justified by their perceptions of which students will benefit the most from a STEM outreach experience. Some respondents favoured self-selection by students to encourage buy-in and engagement. Hence, a range of different arrangements was reported and every teacher had a different approach and reason for engaging students in STEM outreach delivery.

Of the teachers, six detailed their involvement towards internally running, organising and providing access to students in a school-based STEM club activity. Students' access to this type of outreach varied amongst the teacher responses and took many different forms. One school opened the club to all students; another school ran this just for their Key Stage 3 students, and another for their year 7 students only. The other five teachers, who also followed certain criteria, described their involvement in school-based and out of school activities, and the selection of the students was based on their decision and/or with the outreach providers.

Nationally there has been a great focus towards young people who come under the umbrella term ‘gifted and talented’, and those who meet the widening participation criteria (underrepresented socio-economic and ethnic minority groups) (Ofsted 2015). DCSF (2008) defines ‘gifted and talented’ as those children and young people with one or more abilities developed to a level significantly ahead of their year group (or with the potential to develop those abilities). For this study, all teachers expressed their views on giving access to outreach based on student ability. Teachers 3, 4, 6, 8, 9 and 11 showed a greater inclination towards the higher ability cohort, whereas the others expressed a different view. Teacher 1 felt that selection was often based solely on students’ ability (gifted and talented) rather than considering whether students were interested in a scientific career. This selection approach excluded some students who were really interested in gaining access. Teacher 5 felt that too much focus was given to the most able (top set) and least able (bottom set). Consequently, this teacher involved students from the *“neglected”* middle set group as sometimes it was not their ability that determined which set they were in and they often fitted the criteria of being suitable to take part in a STEM outreach activity:

“I think with the team activities, the middle sets were a really good group to do it with, because they’re a range of abilities, so when they’re put into teams, they can help their friends… also, they don’t get a lot of focus. You know. We’re always worrying about the top – the A-stars – and the [borderline] Cs… we forget about the Bs and the Cs in the middle. Because there are able students; often they might be in a middle set because of work ethic or, you know, things like that, and it’s not ability that’s necessarily holding them back, so yeah, I think they’re a good place to focus”.

Teacher 5

Teacher 10, who was the only physics specialist teacher at his school, for an extended period taught the top set science group and during this process he aimed to recruit more students to study A level physics. He reported students’ results for GCSE physics were better than ever before, and further commented, *“The actual enrichment outside of it [students’ physics lessons] is what is actually swaying the kids”*. Thus, to increase the pool even more, he explained how from September 2015 he would be teaching the set 2 group and also giving them a greater opportunity to get involved in the enrichment too. An approach adopted by Teachers 1, 6 and 10, for activities which were relatively long-term, was to select students they considered would stay committed, showed enthusiasm and were interested to get involved. Teacher 10 even used an application process, which, in itself, helped to generate excitement:

"If we've got competition for it – it's either, you know, we go on the first-come-first-served basis, and it shows the most organised and the most keen people get the place, or we even say you have to apply, and you write an email or something to justify why we should take you up for this opportunity. And then they get more excited about it in the first place, they know what they're being taken on, you've advertised it as saying, 'This could be a great opportunity to take part in this at university or to see what this career is like', or something like that, and they get a chance to become excited".

Teacher 10

Similarly, Teacher 7, as she noted a comment from her students, gave her view on the intensity of the message that gets across to the students when they acknowledge who gets selected. She therefore is keen to brand the STEM outreach as a reward for hard work and good attitudes:

"One of the students commented that, actually, they thought it wasn't fair that they'd been the only ones that had been picked. 'Cause in that session, it was targeted at higher-ability children… [but] if you sell it in the right way, as a reward or as a 'you have really impressed me in your science lessons so we're going to let you go on this challenge day' – if it's sold in that way, they [lower-ability students] want to do it too".

Teacher 7

Macdonald (2014) emphasised that when "elite" students are selected for certain outreach activities, it has the potential to negatively reinforce students' perception that 'STEM is not for them'. This can further demotivate students not to consider STEM beyond GCSE. The views from this current study outline a similar message, as Teacher

2 described the importance of ensuring all students are given an equal opportunity regardless of their ability. However, he also highlights how, in practice, some practitioners do not provide equal opportunities, favouring enthusiastic and gifted students:

“…you’ve got to hit everyone. You know, you can’t just have enrichment for the most able or just enrichment for the naughtiest, ’cause otherwise other groups get disillusioned… speakers generally are more willing to put themselves out, especially university ones, if they’ve got kids who are bright, intelligent and work hard”.

Teacher 2

This raises an important issue, questioning whether universities are narrow-minded when they appear to show interest in engaging only *“suitable”* students. It is therefore important to highlight the need to challenge university staff and train outreach practitioners to motivate the less engaged and to manage disruptive pupils.

Another issue raised by the teachers was the level of clarity about the nature of the activities provided, as it seemed this could affect teachers’ ability to effectively select students for the outreach activity. For instance, Teacher 1 suggested that having more information prior to the event and providers being more precise with their use of terminology would greatly facilitate teachers with the selection process:

“Yeah, well, I think you – you’re often selecting a group of students, so you’re selecting 28/30 kids, and you’re hoping that the vast majority of them are going to enjoy it. But also, quite often, you’re sending people not really knowing what it’s going to be like. I mean, for example, your – you’ve got an invitation to a lecture for Year 8s. Now, ‘lecture’ is a concept very different from ‘teaching’ for year 8s. So is that lecture actually going to be sitting quietly, listening for an hour? Because if it is, you’re then going to necessarily choose the students with the longest attention span and the kids who would most likely be able to cope with that. And so – but you don’t know. Just ’cause it’s called ‘The University Lecture’, it might be something where they’re actually a lot more active”.

Teacher 1

Overall, the responses varied about how students are chosen to take part in STEM outreach activities. Some teachers were strongly passionate about providing all students with an equal opportunity while some provided access mainly to high calibre or committed students, primarily because of the nature of the events.

Varied views were also expressed on access to STEM outreach and selection process by the practitioners (section 4.3). The majority of the practitioners were passionate about providing outreach to all students, instead of restricting it to gifted and talented groups. In their opinion the selection process should be based on the nature of the activity. Thus highlighting the need of discussion and dialogue between the practitioner and teacher before the outreach activity.

5.4 Year groups chosen to participate in STEM outreach

Students’ attitudes to, perception of and understanding of STEM subjects and careers are formed and developed at different stages during their educational journey (Archer 2013; Adecco 2015). Thus, to support learning at all stages, STEM enhancement and enrichment activities are focused on a range of academic year groups (Finegold 2011; Parliamentary Office of Science and Technology 2011; Mann and Oldknow 2012; Perkins 2013).

In this study teachers’ views were captured about which was the most appropriate academic year group for introducing to STEM outreach activities to effectively support students’ understanding of and interest in STEM subjects and careers.

It was found that many teachers described the target group based on the intention of the activity and for five of the eleven teachers; the purpose of the activity was a key driver towards their response to this question. The responses of the teachers are summarised below (see Figure 5.1).

Figure 5.1: Target groups to participate in STEM outreach

In comparison, the practitioners' view (see Figure 4.1) was that it is better to start raising the interest of the students' earlier but not later than year 7. In their opinion year 5-9 was "planting the seed" phase. They also highlighted that the "career focus" and to "support decision-making" outreach is important for year 10-11. The practitioners expressed the same views as teachers that the focus of outreach activities for year 12 should be "to retain".

Many teachers considered providing outreach access to year 7s and 8s was an effective approach if the purpose was to introduce, excite and motivate students towards enjoying and appreciating the concept of STEM:

"When you hit the year 7s with enrichment, it just bolsters their enthusiasm and staves off the pubescent malaise for another couple of months of – and they're excited about their subjects".

Teacher 2

One teacher said early access to STEM outreach can impact the development and understanding of their view of STEM prior to making career decisions:

"…in terms of sort of raising aspirations and sort of helping them decide what path to go down, probably the younger the better, 'cause I think the students are that much more impressionable and ready to just – you know, a bit more open and they haven't already been funnelled into particular GCSEs or particular A levels".

Teacher 5

A similar comment was made by another teacher, who currently at her school is the Head of Science. She stated, activities for year 7 should give them the opportunity to see and understand what is out there rather than being career driven:

"Sometimes I think some of the things in the past that has been offered to year 7 have gone over their heads because they're not ready to make decisions about careers and they don't need to. They just need to have the opportunity to be informed about what happens in the world and what's out there".

Teacher 1

Many (for instance The Royal Society 2014a; House of Commons Science and Technology Committee 2014) have highlighted how students from a young age develop a perception that STEM are hard subjects and suitable for only the most able students, later acting as a barrier towards positive attitudes and learning in STEM.

To counteract this effect, one teacher considered that it was necessary to start outreach early, as he believed it had the potential to break down some of the stereotypes that exist amongst students and challenge their misconception of STEM.

However, some teachers felt younger students were not mature enough to fully benefit from outreach activities. Instead, they recommended focusing on year 9 students or older. Teacher 7 acknowledged benefits for all ages if outreach is done well, but identified year 9 and 10 students especially that could benefit more due to their *"level of maturity to appreciate"* and the ability of outreach in *"influencing their life choices"*.

For other reasons, Teacher 10 felt that older students were a better target group:

"…it's almost like you're wasting your energy, to a certain extent. Although, especially with years 7 and 8, they can't – they can't distinguish between – if you give them an exam paper which one was physics/biology/chemistry. It's all science at that point".

Teacher 10

This suggests a narrow focus in his mind for STEM outreach in relation to information; he does not recognise the potential value in inspiring younger students about the value, power and excitement of science in general, irrespective of whether it is physics, biology or chemistry.

Teacher 10 would focus on year 9 because students have begun GCSEs and are starting to realise that decisions lie ahead of them:

"The best time to start is year 9… Straight away, so it's – I mean, even – well, it doesn't matter, really. As long as it's year 9; then, when they're doing their GCSEs, they realise, 'Oh, that's important for this.' Do you know what I mean? They can see the links, then, and then it starts – then they start thinking about A levels, then. And that's the time where we really focus with them, because half-way through year 9, we go to – from Key Stage 3 to Key Stage 4".

Teacher 10

A preference towards targeting years 9 and 10 students was also shown by other teachers too, as they believed it gave the students an opportunity to understand the relevance of the activity and support their decision-making process:

"I think beginning of year 9 and anytime with year 10, which is age 14/15 would be more appropriate because at that age, they are deciding on what they will want to do in year 12 their sixth form, and then maybe take up something similar in university".

Teacher 6

Providing outreach to those at the later end of Key Stage 4 or in year 13 was seen as distracting by teachers due to there being a great focus on exams. Though teachers recognised how enriching year 12 outreach could help to retain students' enthusiasm as Teacher 5 stated by then they have *"already made up their mind"*.

The overall findings suggest teachers believe that STEM outreach can be effective in enthusing younger students, encouraging mid-secondary students to aspire to a STEM career and may serve to sustain motivation in older students who have already chosen STEM subjects. Five teacher responses indicated a similar view as they stated all students from all years should be given access to outreach, and with quality providers, "*it is never too late… as long as you get the right people, it can change their mindset", Teacher 4),* and so it can be equally valuable across the board.

5.5 Intended effects on students of STEM outreach

The teachers provided a meaningful insight as to why staff from schools/colleges are actively involved in organising STEM outreach events additional to their regular teaching responsibilities. A summary of how teachers believe participation in STEM outreach impacts their students' learning, development and awareness are detailed below:

- Provides an eye-opening experience
- Develops skills
- Increases confidence
- Enriches learning
- Smooths school transition
- Provides experience of a different learning environment

The points listed by the teachers are similar to what the practitioners said in section 4.5. Their shared objectives further strengthen the value of partnership between the practitioners and teachers.

Teachers have found students' experience of STEM outreach to be valuable and beneficial for a variety of reasons. Seven of eleven teachers indicated that outreach has been an eye-opening experience for their students, and as a result students have been exposed to understanding the real life implications of the subject taught at school, and gained awareness of different careers associated with STEM. Teachers felt students were generally unaware of the opportunities that can arise from a STEM qualification and so outreach can play an important role in broadening students' horizons. One participant, with 20 years of teaching experience, stated:

"I think it [outreach] is very important, because the students, when they are here, they do learn it as a subject, but they don't see its implications later in life. They don't see it practically being used in life. So I think having an outreach programme can give them that kind of direction/exposure, and I think that is very important".

Teacher 6

Two thirds of the teachers also found participation in STEM outreach had the potential to enrich Key Stage 3 and 4 students towards developing skills that are needed in other disciplines. They felt as students engaged in certain STEM outreach events, skills that were universal were developed, for instance, communication, teamwork, research and critical-thinking:

"It allows the students to develop other skills rather than just STEM related skills. So obviously you're developing teamwork, you're developing management skills, you're developing collaborative skills, communication skills, and they seem to really enjoy those, as well".

Teacher 7

Some teachers also related how their students were developing leadership and mentoring skills when given the opportunity to lead sessions for lower years. This mainly took place through involvement in school-based outreach events. One school introduced an accredited BTEC STEM leadership qualification, which provided opportunities for sixth form students to lead and mentor younger pupils in various outreach sessions. Some schools used their after school STEM club as a means for providing mentoring opportunities.

5.6 Key strategies to deliver effective and engaging STEM activities

The teachers also provided key observations on the level of impact of student participation in outreach activities. Based on their experience, teachers outlined what they considered to be good practices (+) and barriers (-) towards students' learning from and engagement with STEM outreach. These are illustrated below (see Figure 5.2).

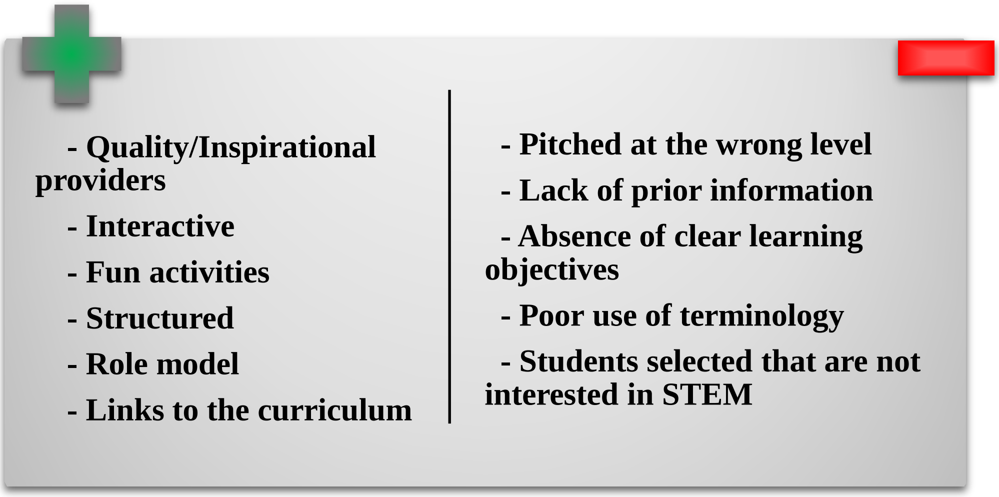

Figure 5.2: Key strategies influencing the degree of impact of STEM activities

5.6.1 Issue of pitch and language

The teachers emphasised the importance of the quality of providers in making a significant difference, whatever the type of activity:

"...that person came in with nothing. He didn't even use my blackboard. He didn't use my PowerPoint, he didn't use my computer; he was just standing there, but he enthused the students so much with his talk, and the way he gave that talk, that was brilliant. So you don't need resources to engage students and get them interested, and I think that was the best out of all the programmes and everything we have done so far. They [students] were thoroughly fascinated about what chemistry can do. What can they do in university and how it can be interesting enough".

Teacher 6

On the other hand, some activities did not generate the same enthusiasm and engagement as they were pitched at the wrong level:

"I'll be honest, some outreach providers from universities, they missed the point of targeting the right age group because they're so used to lecture style…"

Teacher 4

One teacher even withdrew students from activities because the industry provider gave a talk that was inappropriate for the year group. However, she considered this was not their fault and instead pointed towards the training provided, similar to the views of the STEM practitioners:

"I haven't done it this year, and I haven't done it for this particular reason. We had some STEM ambassadors come at the end of last year who work in industry. So, brilliant idea; it was pitched totally at the wrong level. Because – so we'd met before, and we talked about what topics would be useful. It was far too – it was delivered like a lecture, there wasn't any hands-on experience, it was way above, a lot of it… I think the reason why the people were talking in that way because they're used to talking to colleagues of a certain age who obviously are graduates or educated people. They haven't had the experience of talking to children because that's what they are. And they just don't know, so it's not their fault. There needs to be some liaison between STEMNET, us – STEMNET need to see their presentations before they actually do it, and give them some feedback on, I think, where they're pitching it".

Teacher 7

Teachers 2 and 6 were also unsatisfied with the level of delivery by some industry and academic practitioners and found their use of language was not always suitable for school students to understand. Teacher 2 stated:

"…cause people in industry and academia forget what the difference is between a 12 year old, and what they know, and a 13 year old and a 14 year old, so you have to tell

them. Unless they work with schools a lot, they don't know, necessarily, exactly where they are".

Teacher 2

Whilst Teacher 6 felt it was important that the activities were interactive and not just talk:

"…because when we invite university students or someone from the university to come and do a project or something with students, sometimes I feel that the students do not really grasp the content which is given to them… and sometimes the language used is maybe good for university students to understand, but it can be a bit tough for the school students - so to bring it down to their level of understanding and make it a bit more fun, rather than just a talk about things".

Teacher 6

Teachers also felt the terminology - STEM, influenced the degree of student participation in STEM outreach. Teachers 5 and 7 found students do not always connect themselves with this term as strongly as we perhaps would like them to:

"Cause I think for them it might come across as a bit of an isolated, 'we're going to talk to you about STEM today', whereas maybe it could be used more commonly as a term as an industry".

Teacher 5

Whereas Teachers 1, 2, 4 and 7 found those providers who could relate their material to the curriculum created more impact, however many STEM practitioners from this study did not convey the importance of this:

"I think the team that they got actually work in education and, therefore, are aware of the current in advancements and the changes and they do align it really tightly actually".

Teacher 4

5.6.2 Nature of activities

Five teachers felt that interactive, engaging and stimulating activities were essential tools for engaging students. They found when the students' do not have an engaging experience they are not enthused about STEM:

"There has to be more interaction, there has to be more group work and there has to be a fun element to it… all that needs to come in if they want the students to enjoy these things. And sometimes it can become a bit dry when it is just being lectured on or just talked about. When you put up a PowerPoint and show it to them, they're not interested… a talk is the least effective. They are switched off after five minutes of any talk unless it is made very interesting".

Teacher 6

To engage the students effectively, outreach needs to involve the right balance of practical activities and discussion. Teacher 4 reflected on a past experience and detailed the amount of time spent talking and the time allocated towards students getting actively involved was not suitable, and thus it defeated her purpose of engaging students in that type of session. The Wellcome Trust (2011) found hands-on practical activities were a particularly appealing element towards impacting students' views on science.

Sessions that involved active pupil participation are perceived as more beneficial since teachers felt that this enabled their students to gain the opportunity to learn and apply other key skills during their involvement in STEM outreach. This view is also found in the BG Group's STEM Education Learning report (2013) which states that "interactive, contextualised and practical activities are particularly engaging for young people although there needs to be an increasing emphasis on theory as students get older" (BG Group 2013: 7):

"The interactive activities are normally most effective, so normally team challenges, whether that's, you know, a building activity or designing or presenting as a team. I think they've got a lot of universal skills in those activities - it appeals to the strengths of the different students".

Teacher 5

Another element that teachers found useful when enhancing students' experience of STEM outreach was incorporating projects into a structured mini or long-term project. Involving students in such activities meant the students were more focused as they have to work on long-term goals over a period of time. This approach also creates an opportunity for students to feel a sense of achievement when the project is completed:

"You know, anything that was long-term, to me is more valuable. The long-term projects 'cause they're always doing it, they're always thinking about it. It's there at the front of their head… if they don't see something at the end of it, the numbers will dwindle, even if they think it's fun".

Teacher 10

In general, teachers expressed a positive attitude towards engaging students in inquiry led projects and felt this model is beneficial in several ways, supporting effective engagement and opportunities to learn. Inquiry-led learning engages students in an active role such as problem solver, decision maker or investigator and enables them to "dig into complex, challenging, and sometimes even messy problems that closely resemble real life" (Intel Corporation 2007: 1).

The teachers also commented on the significance of engaging students with male and female role models to support the principle of providing students with an equal opportunity in STEM from a gender perspective. Furthermore, they indicated a strong preference towards exposing students to a different environment (like the university) where they can experience new facilities and an opportunity to engage with specialists from their field.

5.6.3 Integrated rather than isolated events

Teacher 10 expressed his views on one-off interventions and the importance of following up the activities:

"Yeah, when they go out on one-day things, I get someone else to go - I might organise it, but I'll send someone else 'cause I don't think they're as beneficial as a long-term project. Anything that's, like, one-off, if it's not followed through, it's pointless, 'cause the next day – 'cause, like, when I did this – I did it with the year 8s. We made these spectrometers. Yeah? And then we did this – we did these, like, Cartesian divers. 'Cause we didn't follow it up, they forgot it. All they could remember was, 'Oh, yeah, I saw a rainbow.' 'Cause that's what a spectrometer gives out. And I thought so these one-off things are no good unless they're followed up".

Teacher 10

Similar views have been described by other authors (Laursen et al. 2007; Archer 2013) who have found one-off events are perhaps not the ideal approach for making a difference to students' future career choices. Their emphasis on the need of providing students with multiple interactions with outreach is to ensure students' overall experience is broad and more likely to have a positive impact.

Whereas, other teachers would have liked to have information provided prior to the interaction between their students and outreach practitioners, and as a result viewed some outreach as a *"lost opportunity"*:

"Sometimes the students come really cold to it, and they don't really know what they're going to do… we hadn't primed the kids, we hadn't prepared them, they hadn't sort of investigated what questions they wanted to ask about careers, they didn't really know what was going to happen, we hadn't prepared anything afterwards in terms of follow-up and… and it all just sort of fizzled out a little bit. It felt like a bit of a lost opportunity, and sometimes outreach activities can be a bit like that".

Teacher 1

Teachers 5 and 6 also put forward similar concerns, and Teacher 6 felt the outreach activity did not always send a clear message:

"At the end of all that, if they [students] really do not know why they have done it, it doesn't serve the purpose".

Teacher 6

5.6.4 Summary of key factors

Many of the views expressed by the teachers were echoed by the practitioners (as discussed in Chapter 4). In particular, in terms of the nature of the activities, the value of engagement and interaction have been universally acknowledged. However, it is clear from the experiences that the teachers relate that there are still many outreach events which rely heavily on a talk with PowerPoint slides and these appear to generally fail to achieve the desired outcome (apart from the one truly inspirational example quoted).

The feedback from the teachers clearly underlines the importance of training, not only in terms of the nature of the event but also in relation to use of appropriate language and pitching at the right level. Teachers can play a valuable role in advising here, but this needs to take place in advance of the event.

A recurring theme is the importance of involving teachers both before and after the event. Good communication is vital here. With a clear view of what will be covered, teachers can help to prepare students for the event so that they gain the most from it. Likewise, where material aligns with the curriculum, they can build on an event after it has taken place to reinforce the messages delivered from STEM outreach.

5.7 Approaches to evaluation

In order to improve and enhance the delivery and impact of STEM outreach activities, feedback is routinely collected from students and teachers after many events (RCUK 2011; Chatwin et al. 2012). Here, the participating teachers take on the role of an inside evaluator who speak on behalf of their students, convey their experience and analyse the impact of outreach. Thus, the perspective of teachers is valuable for guiding how to tailor their outreach according to what is effective.

The teachers were asked to reflect on their experience of evaluation methodologies used by outreach evaluators and to detail baseline factors they take into account when they assess the success of STEM outreach.

Five teachers identified students' involvement and attendance in a school-based STEM club as a useful measure. Another significant indicator is the standard of work produced at the end of mid to long-term projects. The students' assessment of the outreach activity is judged not only by their feedback but by the level of enthusiasm associated with the topic and perception of the subject matter. Students who have been inspired will ask connecting questions relating to careers and start using the jargon of that subject. These are strong indicators of interest in STEM. One teacher described how, to become familiar with the level of impact, he would attempt to *"gauge their perception"*.

One teacher, as part of STEM club activity, asked the students to keep a log book of what skills they developed. She felt this enabled the students to self-reflect their interaction and engagement with the club activities and adequately express its impact on learning:

"Students keep a log book… so we introduce the activity, we ask them what their confidence is with that activity, to start with, and they rate themselves somewhere on that scale. And then, in the end, we try to ask them how much they now know what goes into that activity or".

Teacher 6

Whereas Teacher 6 explains, when she initially started, she did not intend to evaluate her STEM club in a formal manner:

"…my idea of starting the STEM club was not to fill in any paperwork. My idea was just to bring in some students, enthuse them with the subject and take them forward and make them curious to know something more. So they should be looking forward to come back to the next session… for me, students coming in, enjoying that one session, learning a scientific concept which can be very difficult to read from a text book, understand it, enjoy it and relate it to the world".

Teacher 6

Measures that supported teachers' understanding of the level of impact outreach contributed to student learning and awareness of STEM subjects and careers were:

- Pupil's voice
- Teacher's instinct/feeling
- Uptake of triple science
- Uptake of the A level subject
- The buzz around the activity
- Asked to repeat the activity
- The same mistake is not being made at the end of the activity as at the start
- Change in attitude, perception and awareness of STEM subjects and careers

Thus, teachers involved in various outreach activities collectively identified a list of proxy measures that supported their observation and understanding of the level of impact outreach participation made on their students.

The types of evaluation strategies teachers considered would give a true and critical reflection of the benefits and issues relative to their students' outreach experience were also investigated. Teachers' suggestions of what they thought were the most efficient methods of evaluating are detailed below.

Many teachers were in favour of STEM outreach providers capturing qualitative feedback rather than quantitative feedback. Similar views were expressed by the practitioners. A preference towards a *"structured discussion"* was shown as one teacher believed this accurately captured the perceptions of students. These teachers felt verbal feedback provided students with an opportunity to be honest and realistic:

"It's [students' feedback] very subjective, 'cause it's obviously views and it's – they've got out of lesson, so to speak, so their view is often very positive… I think discussion-wise is much more powerful, to be honest – interviewing them, rather than a questionnaire".

Teacher 6

The teachers found having a dialogue with the students after the event and gaining verbal feedback was beneficial:

"*If the students have many questions on different subjects and different universities, that [then is] a good sign".*

Teacher 9

Whereas, one teacher suggested a combination of quantitative and qualitative evaluation strategies was effective. She suggested questionnaires could be adopted incorporating a section where students could write as they pleased to quantify their experience:

"I think obviously you need a mixture of both numerical kind of questions based so you've got the continuum line, but also a space for writing a specific and not feeling that you have to write something positive".

Teacher 4

This shows that, even with the use of a questionnaire, the teachers would like the students to have the opportunity to express themselves through written comments. However, in terms of externally provided events, teachers criticised the questionnaires used by many STEM outreach practitioners. One teacher explained that students are often forced to select one of the pre-assigned options or that they do not always thoroughly understand the questions, making it difficult for them to provide a meaningful response:

"…doing a questionnaire's great, but sometimes I find the questions – either they get defensive on the questions, or the questions are too leading and they've kind of forced an answer out of them. It's not giving them a chance to be open. But the trouble is, it's – my issue is, I don't think they're fully aware – or fully self-aware, so they couldn't answer… I mean, like, with these evaluation things, I think it should just be – just sit down: 'What did you find?' You know. Just be more open. Yeah, more verbal… You know, sometimes just getting a feel. Trying to be too prescriptive is not – I don't think it's – it doesn't allow flexibility, really".

Teacher 10

Overwhelmingly teachers spoke in favour of qualitative and/or longer-term evaluation of outreach activities. At the very least, they felt that students should be given the opportunity to provide a *"free text"* written response which was neither forced nor led towards a positive slant. However, they preferred conversations rather than written feedback.

Generally, there were high levels of agreement with the practitioners about the best methods of feedback. However, it was clear from their comments that these methods were often not used. There is an opportunity for teachers to have the type of conversations with outreach practitioners over a period of time and also to identify other factors such as students asking more informed questions about STEM and showing more interest generally. However, for this feedback to be effective there needs to be good communication, post-event, between teachers and practitioners and a clear expectation of what teachers will report. This moves teachers from simply being coordinators or facilitators to active participants in the outreach process.

5.8 Teachers' views on participating in STEM outreach

Teachers have highlighted how participating in STEM outreach activities has directly contributed to their own understanding and benefited them personally. For instance, it has provided one teacher with a stress-free environment where she can interact and engage with her students without worrying about an exam:

"When you've got the students in the classroom, you've got a target, you've got a focus that you're under pressure to obviously cover a part of the curriculum, you've got exams in the distance in your mind – you know, you've got to be focused on that. When you do extracurricular, we can do whatever we want, it's a more relaxed atmosphere, you get time to get to know the students in a more relaxed way, they're able to come up with their own ideas, they – it's fun for them because they're doing what they want to do… that's probably the best thing, really – spending time with the students and not having the pressure of having to get them ready for an exam or get a piece of coursework done or – you know, you've got a test coming and you can't afford to waste time".

Teacher 3

Teachers 4 and 9 described how their involvement in the design of the activities meant the outreach practitioners were able to execute an effective outreach event:

"I mean the National Space Centre are brilliant in terms of they will target what your group is - yes so I go meet them and then we plan sessions together and then they'll come and say look - it's only because I have done a lot of work with them so they know me so they're quite happy for me to go in and co-plan and they'll give me ideas that will say they've got this this this this what do you think would work yes so we co-plan and that's when it's really effective".

Teacher 4

"The electronics workshop - I did – I think – I wouldn't like to take the credit for organising the – for pulling together the actual workshop itself, but I definitely liaised with the professor, and his team, and they – I think my level of involvement was just right, because they possibly would have pitched the level slightly too high for the students, if I hadn't been involved. I just gave them an idea of how to – the level to pitch it at and how to make their activities fit in with our specification and the exam boards, so I was fine with that".

Teacher 9

The teachers expressed that the dialogue and discussion between the practitioner and teacher in planning the activity ensured the activities were suitable and targeted appropriately. Thus, co-planning along with the providers appeared to benefit the teachers as they were satisfied by the process of delivery and by the impact made towards their students.

A key strategy outlined by the teachers was receiving access to the feedback collected by the providers. Teacher 1 along with Teacher 5 indicated a preference towards receiving this:

"I think it would be useful, in some ways, to have – like, for example, if I was working with an organisation that was coming in to run an event, I know sometimes they have their own evaluation for their own purposes. Sometimes it would be useful for the school to have more feedback from that, or for maybe to have a suggestion of, you know, 'this would be a good way of evaluating the impact on your learners' – for our own purposes".

Teacher 1

"And as a school it would be nice to get the feedback, as well. I think if I could say one thing to STEM ambassadors, it would be, 'When you collect these sorts of things, you know, forward us the information, if that's OK, 'cause we'd like to know if the students are liking it or not or…' Or if they're – you know, equally, if they're being silly in their feedback, you know, we need to give them – if we need to prep them how to do it, then that'd be good for everyone".

Teacher 5

Additionally to providers sharing their evaluation feedback, another teacher indicated that she would prefer it if she received a form of training to further support her development as a STEM outreach facilitator:

"I do attend the [Name of Organisation] meetings and events and things like that, just to get more ideas and resources for the club and things like that. But obviously no structured training has been arranged".

Teacher 6

Whilst it should be acknowledged that the teachers interviewed for this study may not be typical of all mathematics and science teachers, it is clear that for this sample, they gained high levels of satisfaction from being actively involved in the planning and delivery of STEM outreach. They describe quite a different view from the practitioners whose discourse was more about benefits for teachers in being exposed to cutting edge science or gaining ideas for things they might do in their own classrooms rather than as active partners in delivery. The teachers presented convincing examples of how their direct participation had improved the quality of outreach events.

5.9 Support from schools for teachers to facilitate effective STEM outreach

Key interventions were identified by teachers to support their role as STEM facilitators. The teachers described four factors they that were integral to enabling them to fulfil their duties effectively:

- Administration
- Financial
- Time
- Recognition

Administration support was an essential element that was identified by many teachers, in particular for those STEM outreach activities that took place at the school premises. Teacher 5 described how, by using school assemblies, he was able to engage and promote the activities and that an improvement in the school online booking system eased his role of organising outreach activities too. Another teacher described that, due to the lack of support from her school, access to students through assemblies or during school time was challenging. She explained that this, therefore, made it difficult for her to hold larger outreach events:

"If we would want something like this on a bigger scale, it would be easier if the school gets involved and it is done in the school time, in an assembly or – the whole of year 8's, for example, are targeted".

Teacher 6

Teachers also identified how timetabling can impact students' access to STEM outreach activities. For Teacher 10 this was not an issue, as his school acknowledged the importance of outreach and so he described that access is provided to large groups of students as outreach is embedded into the school's curriculum and most importantly its ethos:

"We do have also in this school four enrichment enterprise days, where the timetable is suspended and then different year groups do different things… so the school actually does good in that, in that they collapse the timetable, or they suspend it, so these things can happen".

Teacher 10

Some teachers identified financial support as an important factor. Teacher 6 who runs an after school STEM club on a voluntary basis, funds her club herself though feels that her school could do a lot more and at least provide financial support to assist her with consumables. She reported that her school does not recognise or value the level of impact outreach is making, preventing her from enriching her students through various initiatives:

"…everything which I bring in for the STEM club, up until now, was being resourced by myself. If I was using some chemical, if I was using some material, it all came from me. It didn't come from school. So I think if the school wishes to put such things in a bigger scale, it should be properly thought about and it should be properly funded… I can't then think of X robot – buy that for £450 pounds for my students to build it, whereas

other schools do have that kind of funding available, so it should be made compulsory to schools, but then the school should understand that this has an impact".

Teacher 6

This shows the importance of a school recognising the benefits from STEM outreach and that a school's ethos can make a difference towards effectively facilitating teachers' outreach role. Another teacher similarly expressed how the lack of financial support along with time constraints affected her approach:

"It's just organising a lot of time and money and – a lot of time, really. Organising the different trips and making sure that they go to what's out – you know, what's available out there. Trying to mop up as – there's lots of things out there that they can do but we can't do everything, 'cause we haven't got the money or the time to do it".

Teacher 3

Teacher 3, who ran the STEM and Environment club at her school, outlined her experience and struggle with balancing her time with teaching and running outreach. Due to the workload, she sought administrative support, even recommending creating a full-time post:

"Obviously, one of the problems with teaching and trying to run extracurricular is time, so it's basically just having the time to put into researching what's available. It – really, you could make this job into a full-time STEM coordinator. You could just do – there's so much out there that you could do, it could become full-time. There's just – it's never – it's endless, what you could do, so we've done an awful lot. Every year, we do do a lot of stuff with STEM, but you could do more".

Teacher 3

Similarly, Teacher 4 also described problems most teachers share and that is being under time constraints, so making it difficult to organise outreach events. Therefore, her approach was to call in external providers to facilitate the events, though acknowledged that this coordination activity could be taken up as a full-time role too:

"The problem with it is, if you teach full-time, then obviously logistically it is quite difficult to organise in school. So I would tend to pick external providers that basically come already set up. Obviously there's a lot of funding out there and sponsorship available… you could – I mean, you could organise outreach as a full-time job".

Teacher 4

Receiving that level of support from the school, as one appointed a subject specialist teacher and the other created and implemented a new role to support the science department with coordinating outreach activities, was appreciated by their fellow school teachers:

"But the problem is, we're under pressure as teachers, we're under ever-increasing time pressure now, so we could never have done as much enrichment this year as we have if we hadn't had [Name of a staff member], whose job it is to do that stuff. You know, he's intervention manager, which is half-way between taking small groups out of classes and teaching them, and organising enrichment events".

Teacher 2

Whereas Teacher 6, who runs the STEM club through her personal choice, expressed that despite being committed and giving up her own time, she would prefer if some recognition from her school. She explained:

"I also feel that, sometimes – once I remember having talked to a senior member of leadership team, and they were saying that, 'Why don't we do it on a bigger scale?' But then you would need manpower to do that and time… it's quite hard, unless it is put in the form of a responsibility to someone… but then there's a difference. I'm a STEM coordinator for the name of the… I'm not paid anything extra. I'm not labelled as such. It's my choice I'm doing it. So there should be a profound role for a STEM coordinator and there should be some kind of incentive. I'm not talking about the money part of it, but there should be some stuff available for the club to use".

Teacher 6

The recognition that she looked for from her school was for them to appreciate what she does and acknowledge the impact this brings.

Nevertheless, one teacher did not view it as his responsibility to promote STEM. He suggested with the funding cuts, the emphasis on STEM outreach had fizzled out. He expressed that as there was no STEM coordinator with a designated role, no-one from his school voluntarily took it forward, and thus suggested appointing a STEM coordinator who manages this would be a preferable solution:

"I would say that I care about science and see it as important, but I don't feel like it's my agenda to push STEM. 'Cause there used to be STEM coordinators and things. In schools – used to be a big thing. But now they've – the funding's gone out of that. So there isn't really anyone in the school whose job it is to deal with the STEM... and that would be really good, if there was someone – like you know you're doing the Spiritual, Moral, Social and Cultural (SMSC) stuff? If you were saying, 'Right, you're doing the STEM stuff as well. You need to push STEM'. Which they did do three years ago, but they've changed that now".

Teacher 8a

The teachers interviewed had high level of commitment towards STEM outreach and reported that there is a wide range of activities available for their students to participate in. The extent of opportunities presented a problem in that they needed to select which ones to become involved in. Furthermore, the time required to organise participation in a wide range of activities is extensive. There was a common view that, in most (although not all) schools there was a mismatch between the supposed importance of STEM and the value demonstrated by the resources allocated and the recognition given to those taking STEM forward.

Several teachers suggested that a full-time STEM coordinator role could be highly effective. By creating such a role, schools will be clearly allocating time for the required organisational tasks and (more importantly for most teachers) providing recognition of the valuable work they do.

5.10 Key strategies to facilitate effective STEM Outreach

In this section, the teachers describe support initiatives they considered essential from the providers of outreach to impact their role as STEM facilitators for their students. The type of support from the providers was broken down into two key themes:

- Consistency and quality
- Communication and clarity

A negative view on the level of interaction and inconsistency STEM outreach practitioners provided was expressed by the teachers, acting as a barrier towards teachers making a positive contribution through outreach. Along with wanting committed long-lasting ambassadors, teachers also reported that they would prefer it if the speakers were reliable, trained and had the ability to effectively link their activity to the curriculum. Comments made by teachers that supported this view are summarised below.

Teacher 3 expressed her preference for wanting consistency and quality from the providers and detailed that developing long-lasting connections with the STEM practitioners was often difficult:

"I've had people come in from the university to help with my STEM groups, but they've never established themselves. They've never really lasted".

Teacher 3

She further describes how her experience with STEM practitioners was not always appealing:

“This year we had two students from [Name of the university], from the engineering, and one of them was excellent. The other one just let us down and didn’t come”.

Teacher 3

Wanting consistency, reliability and overall more involvement from STEM practitioners was, therefore, conveyed by Teacher 3. As described earlier, another area teachers found disruptive and problematic was often if the activity the practitioners provided was pitched at the wrong level. Of those teachers, two further detailed how this was not their responsibility to ensure talks were delivered with efficiency and were communicated in an appropriate manner, and instead highlighted a need for training and supporting them towards becoming effective communicators:

“We’ve had some people in and we’ve gone, ‘Oh, well, you’re no good’, and we just don’t use them again. And it wouldn’t be worth our time to invest in developing speakers and saying, ‘Oh, you could be good if you did this, that and the other’. That’s not our role. You know, we’re the end-users”.

Teacher 2

“I mean, these people are giving their time willingly, on a voluntary basis, so there needs to be more coordination there, I think. ’Cause they’re trained … by the people that run the STEM organisation in the [Name of organisation]… but I still – they’re pitching it too high, and we, as teachers, haven’t got the time to train them of how to deliver… so, you know, whether they could do that in a whole sort of… little training session – so have one training session of ‘this is what you could be doing’, and then another training session of – yeah. ’Cause then, actually, if they just had one presentation and then advertised it – so ‘we can offer this’, that would work a lot better”.

Teacher 7

Teacher 7 also highlights her view on ambassadors delivering outreach for different purposes. She finds it rather effective when STEM practitioners connect their delivery with the curriculum, and especially when they have taken input from the teachers and students to support the improvement of the activity. Thus, making it more relatable and a valuable experience for herself and students:

"So, often, if it's been sponsored by a company, what they've done is they've gone out and they've gone and trialled it, and they know it works and they've linked it to the curriculum, and that's good. If it's just a STEM practitioner coming out themselves, that doesn't work as well. So the ones that are sponsored by the companies and are specifically – have been written for a particular reason are good, normally".

Teacher 7

Here the teachers appear pragmatic as they would prefer if the material delivered by the provider is linked to the curriculum.

Another form of support the teachers identified was associated with gaining clear information on resources and funding opportunities. Although teachers showed some awareness about gaining access to this information, they considered this could be improved as it was not always received by the right people within the school. For instance, Teacher 1 reported:

"I think if you spend a bit of time looking, there are, you know, events run by universities and industry and there's funding available for various things, but the information doesn't always get to people… there's no sort of central hub; there's no central website that you'd look at – look to, or something like that, because things come from different organisations".

Teacher 1

Thus, improvements in the targeting and provision of information and resources by the providers were identified by the teachers as ways to support them with promoting and organising more outreach.

Teachers 4, 5 and 7 expressed the importance of ensuring that the activities are designed well and that there both quality and consistency are present. The teachers shared their experience and overall wanted the providers to be a lot more explicit and detail what they can provide through an easily assessable approach:

"Well it is supposed to be a practical that they did - on paper they said even through liaison based it's practical based and all this but actually when it came to it they talked for, we have one hour lessons and they talked for good 40 minutes and 20 minutes was the practical - which actually by that point most of the students were disengaged and therefore they could not even engage in the practical that was actually useful so it was about getting that balance isn't it".

Teacher 4

"I would say one of the main issues is not always being communicated exactly what the agenda of the day – you know, what the itinerary might be until it's pretty soon before the day. Sometimes it – I mean, some people have been excellent about that and they've given me a day-by-day thing, but sometimes you might just go, 'OK, a title.' And you don't really know what the students are going to be doing. And, yeah, for some students it would probably be beneficial to give them a bit of a prep – a bit of a… I think with the university days, that's never been a problem, 'cause they've been very good at telling us what they're going to be doing in the lab, so we've been able to get them ready - So, yeah, maybe a little bit more of an idea what we're doing – that might be a good way of – you know".

Teacher 5

"'Cause the other aspect of STEM ambassadors is that it just – it'll say, 'Dah-de-dah-de-dah-de-dah from this company'. And you don't know what they can actually offer you".

Teacher 7

Teachers highlighted two issues as of key importance for the success of STEM outreach: quality and communication. It is clear from what they reported that they have variable experience of both.

In terms of quality, their experience was that usually *"set piece"* presentations by companies had clearly been well-rehearsed, not only in terms of slick audio-visual resources, but also in terms of being well-planned to align with the curriculum. Such events were usually pitched at the right level, possibly because the presenters deliver them many times in different schools. On the other hand, STEM ambassadors are often very variable in quality (with some not even turning up). Teachers identified a need for good quality training to enable ambassadors to be effective, but as shown in section 4.7, practice regarding training is very variable.

Some teachers adopt a very pragmatic approach to low quality outreach. They react along the lines *"well you're no good… we won't use you again"*.

As has become a reoccurring theme throughout Chapter 4 and this chapter, effective communication between providers and teachers is absolutely essential to maximise the effectiveness of outreach events. Even if the teachers are not included as active partners, they still need clear, accurate information to ensure that appropriate students are selected to participate and that relevant preparation is given to these students. Also good communication enables them to easily identify the events most suited to their students.

5.11 Influence on career choices

Teachers were also questioned on whether they considered they had an influence on the career path their students choose to take.

The teachers said this depended on many factors and that for some this was the case and for others it was not. Teachers 4 and 11 said their responses depended on the number of contact hours, and suggested the level of interaction they had with their students perhaps increased the level of impact. Teacher 1 described a neutral effect and Teacher 9 detailed, *"If teachers have the power to influence or to encourage students to take a subject, then we also have the power to put them off"* too. Thus, the impact could be both ways as he believed that as a teacher he has the capacity to encourage as well as demotivate.

Teacher 2 explained that most of the students have no experience of the subject other than what they learn at school. The teachers are what the students know about the subject – they become the *"face"* of the subject to their pupils. As a consequence, many pupils' knowledge of the nature of and opportunities for subjects not taught in schools, such as engineering and computer science is generally very limited. Teachers 7 and 10 instead described their role as a facilitator who provides students with guidance and increases their awareness and understanding of the various opportunities and choices.

Teacher 7 explained:

"I wouldn't do it as small as a career path. I think, what's the point in being a teacher unless, actually, you are trying to have a positive impact on the life choices that they make? So not me as a teacher; I see my role as… a facilitator to show them choices. I think offering the widest possible number and amount of experiences that you possibly can, to allow them to make the correct choices for themselves. 'Cause I wouldn't want to influence them, 'cause that's not my choice – [rather] to show them what's out there".

Teacher 7

5.12 Key points from analysis of teacher data

Therefore, the key messages brought forward from this analysis are;

- Dialogue with the teacher is crucial before and after
- Dialogue with the students can capture effective feedback
- Involving teachers as active partners throughout can produce high quality events
- Good pre-information allows schools to prep pupils appropriately
- Links to the curriculum are important
- Sometimes universities seem only interested in high achievers
- Proper training is needed for STEM ambassadors and others
- Schools ethos can support teachers delivery of outreach
- Teachers want recognition of their efforts
- Still heavy relevance on goodwill

The analysis presented in Chapter 4, demonstrated a wide range of variability in many aspects of practice related to STEM outreach. Since the sample of practitioners selected consisted of experienced staff, it is likely that over the whole of outreach provision there is even greater variability. The experiences related by the teachers confirmed this variability, not only of practice but also of quality. Teachers reported having experienced exceptionally inspiring events but also having encountered providers they would never use again.

Some of the practitioners identified key roles for teachers, particularly in terms of evaluation. Practitioners discourse was more extensive in the benefits that teachers could gain from being a participant/observer of outreach activities. Teachers discourse was far less about benefits to their professional development and much more about how outreach activities can be enhanced through their active participation in organising, planning and delivering events. In summary, participants are more likely to think of a provider-recipient model whilst teachers would prefer a partnership approach.

5.13 Summary

This chapter presented an in-depth qualitative analysis of the findings from the teacher data and discussed results from the semi-structured interviews with secondary school/college teachers involved in facilitating STEM outreach activities. As well as detailing the strategies teachers take into consideration on student access, it also described their perception on the impact and evaluation of STEM outreach. Their views on the factors that influence the chosen target year group to participate and the strategies towards improving the evaluation process were summarised. This further outlined the key elements considered by the teachers to support their role as a facilitator and as an influencer on students' career choices.

Chapter 6

Student Data Analysis

6.1 Introduction

This chapter outlines the student data analysis and presents a discussion of results from the quantitative and qualitative data collected from the GCSE, A level and first year STEM undergraduate students' questionnaires (see Appendices D, E and F for a copy of the student questionnaires).

The questionnaire responses detail student participation in STEM outreach. The responses have been analysed according to gender and different academic year groups. Recommendations towards improving students' experience of outreach are discussed and the overall impact of participating in STEM outreach is shown. Key influences on students' decisions regarding course selection are outlined and students' perceived understanding and awareness of STEM subjects and careers are discussed.

After providing an overview of the responses given by the three academic groups of students (GCSE, A level and undergraduate), their likelihood of aspiring to a career in STEM is also explored and factors that influence students' career aspirations in STEM are investigated. The results from the analysis of qualitative data are also presented, including students' perceptions of STEM and their views about how to enhance the uptake of students studying STEM at higher education. The results presented in this chapter address RQ 3 and 4 presented in section 3.5, namely:

RQ 3) What are the students' perceptions of their understanding/lack of understanding of STEM subjects and careers? Is there a significant difference in the level of understanding of students who have participated in STEM outreach compared to other students?

RQ 4) Is there a significant difference in students' aspirations for a STEM career amongst those who have participated in STEM outreach compared to other students?

Throughout this chapter, there is a focus on differences in student responses by gender, ethnicity, socio-economic background (parent's degree status and entitlement to FSM) and whether or not a student had participated in a STEM outreach activity. The analysis provides a valuable insight into the differences associated with those underrepresented in STEM and effectively highlights the impact outreach has had towards inspiring students to pursue a career in an area of STEM.

6.2 GCSE student sample

A total of 661 GCSE students from nine schools completed the questionnaire (see Appendix D). The students were in years 10 and 11 when they completed the questionnaire during the period May 2014 to October 2014. Of the sample, 44% were males and 56% were females, and the majority were from a White ethnic background (65%). Within this sample, there were two students who reported their ethnic background as other (a female Arabian student and a male who did not specify his ethnic origin). Hence, due to the sample size for this category being relatively small, these two participants have not been included in the analysis of student responses when considering statistical relationships across different ethnicities. Personal details provided by the students are summarised in Table 6.1.

Ethnicity				Entitlement to Free School Meal (FSM)		One or more parent(s)/guardian(s) previously completed a University degree	
White	Black	Asian	Mixed	Yes	No	Yes	No
65%	6%	22%	5%	14%	86%	50%	50%

Table 6.1: Details on students' ethnicity and socio-economic background

Overall the students represented a varied sample including different socio-economic backgrounds. A significant association between parent's degree status and entitlement to FSM was also found: and fewer pupils who were entitled to FSM had parents who had degrees (19%) than non-FSM pupils (54%) ($p<0.001$, chi-squared test).

Students' entitlement to FSM and whether or not a parent has a degree was further explored between different ethnicity groups using a chi-squared test (X^2) and Fisher's exact test (FE). Table 6.2 presents the number of responses and corresponding p-values.

Response: "yes"	White	Black	Asian	Mixed	p-value	Test
Entitlement to Free School Meal (FSM)	11%	21%	18%	9%	0.062	FE
One or more parent(s)/guardian(s) previously completed a University degree	53%	71%	39%	52%	0.004**	X^2

Table 6.2: The association between students' ethnicity background and entitlement to FSM and parents with a university degree, and; Key: * $p<0.05$; ** $p<0.01$; *** $p<0.001$

The results showed that there is a statistically significant difference in students responses based on their ethnicity and whether or not a parent had completed a university degree ($p=0.004$, chi-squared test). Of those, students from a Black background appeared to have a greater proportion of parents that had a degree (71%) and a lower proportion from the Asian students (39%) than those from White and Mixed ethnic groups. They were also more likely to be entitled to FSM (21%) than the other students but this was statistically not significant ($p>0.05$, Fisher's exact test). Thus, a significant association between ethnicity and parents' degree is observed, suggesting that they are not totally independent of each other.

6.2.1 GCSE student participation in STEM outreach activities

23% of the sample indicated that they had participated in STEM outreach activities. Key information on their involvement and experience is detailed below; this includes such things as the school year they were in, when they took part in STEM outreach, followed by the estimated number of sessions attended, their average length of activity and the STEM subject(s) their activities related to (see Figure 6.1). As the survey allowed students to document multiple outreach experiences, the percentages for 'school year' and 'STEM subjects' is greater than hundred.

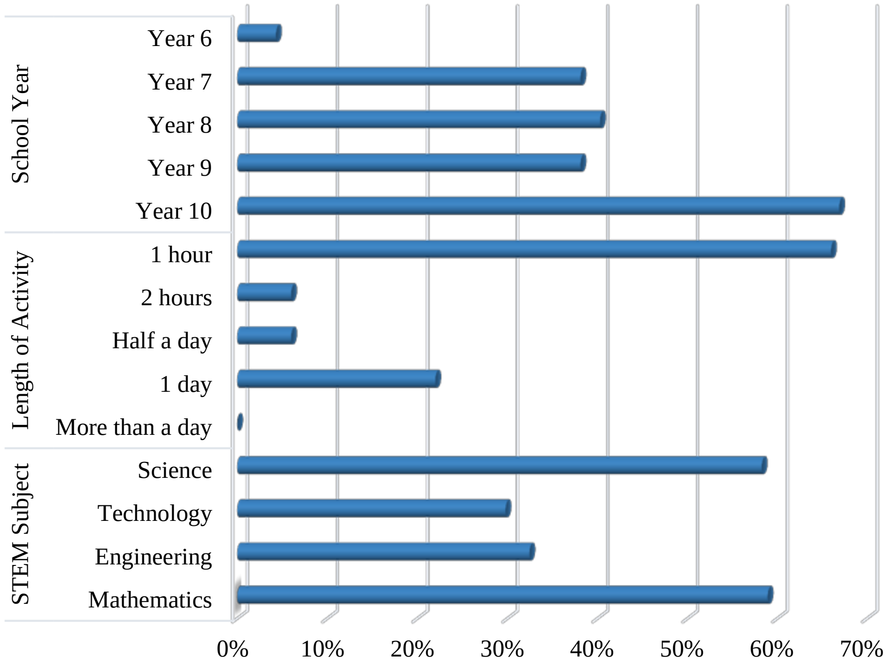

Figure 6.1: Details on student participation in STEM outreach activities

These results indicate a level of impact as students were able to recall and share information on events that took place in the past, which for some was more than four years ago. In addition, most students for this sample were involved in an hour-long activity and no students had taken part in an activity for more than a day. Consistent with other studies (Finegold 2011; Straw, Hart and Harland 2011), this sample also showed activities related to the two most common STEM subjects: science and mathematics (57% and 60% respectively), indicating that "overall, the picture was encouraging, though not uniform across STEM subjects" (Finegold 2011).

The students were involved in a range of activities, including engineering days, programming, building houses using newspapers and solar panels, mathematics challenges and science experiments. The type of activities they interacted with is illustrated below in Figure 6.2, and many were involved in a range of activities, the two most common being competitions (52%) and STEM days (37%).

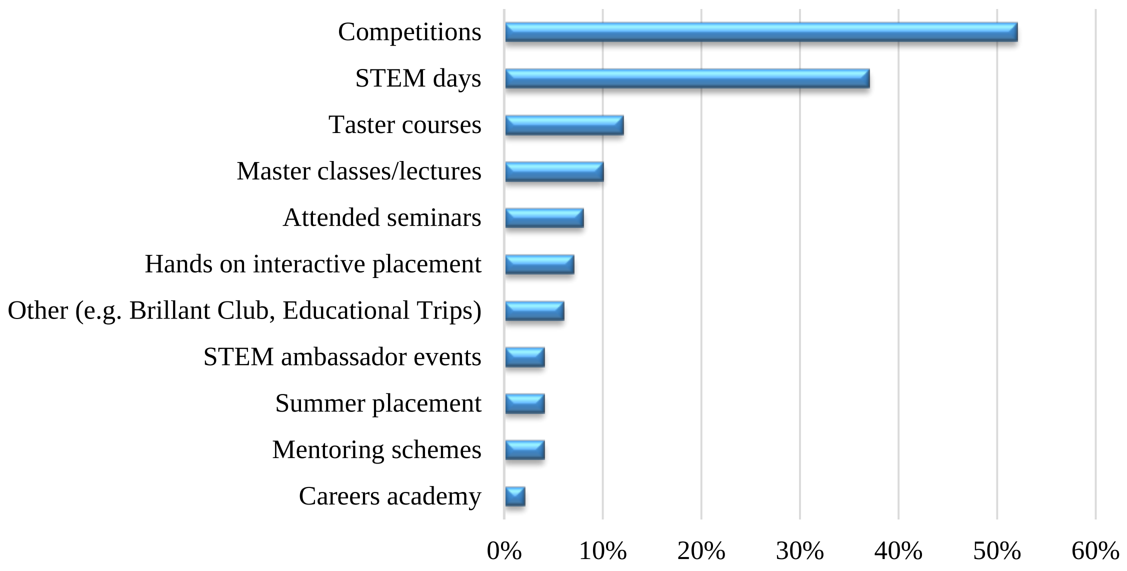

Figure 6.2: Student engagement in a type of STEM outreach activity

Students also provided recommendations on the areas they thought required addressing for future outreach improvement, which are presented in Figure 6.3.

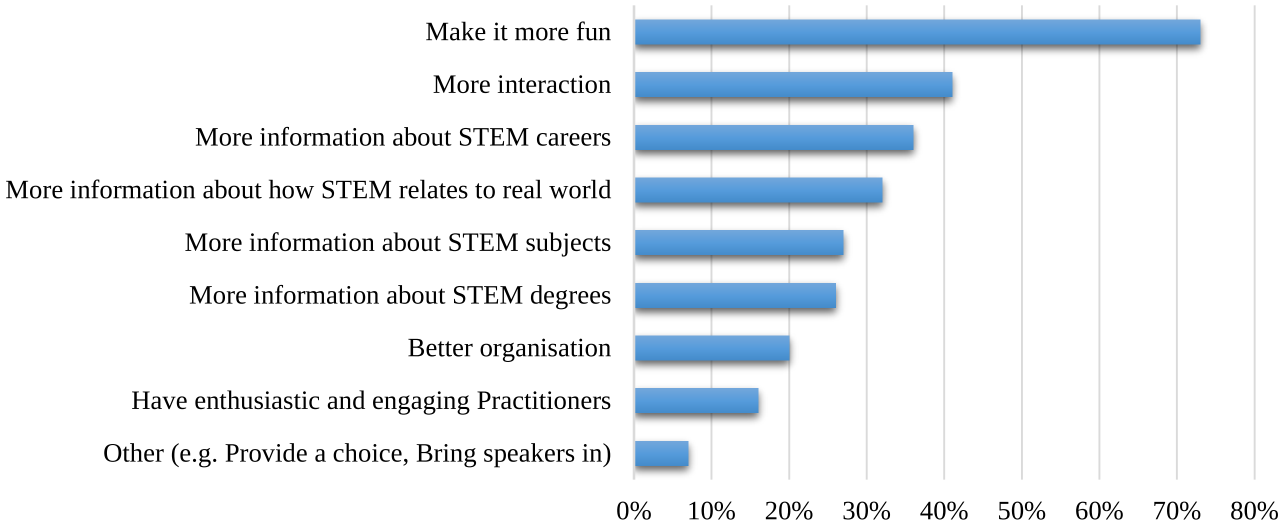

Figure 6.3: Student feedback on improving STEM activities

These findings highlight a key message, particularly since many providers of STEM outreach promote their activities as *"engaging, fun, enjoyable, interactive etc"* and attempt to engage students in a range of STEM subjects. A report by the Wellcome Trust (2012) supported these findings as they reviewed the impact of informal science learning and reflected on factors that engage and disengage students of age 11-16 in out-of-school activities (Lloyd et al. 2012). Their study exploring the challenges, found "fun as an important driver" for students of this age to experience whilst engaging in outreach type activities. The concept of "making experiences and content relevant" and, therefore, developing a learning environment that was enjoyable and interactive was further emphasised.

Another study by the Wellcome Trust in 2011 investigated young people's views on science education, which highlighted that providing students with practical, hands-on and interactive experiences could also potentially increase the likelihood of student engagement and participation in the subject. Science lessons that were fun seemed to positively influence their interest in the subject. Though whilst STEM outreach providers frequently describe their activities as "fun and interactive", it appears that they are not satisfying the students who want more fun and interaction in the activities.

This has also been indicated in teachers' views (Chapter 5) that some outreach is "too much talking" and pitched at the wrong level.

6.2.1.1 Impact of STEM outreach on GCSE students

The percentage of GCSE students having certain characteristic of engaging with STEM outreach is shown in Figure 6.4. For each association (i.e. differences in student responses by gender, ethnicity and socio-economic background), using a chi-squared test the statistical differences and the p-values are presented.

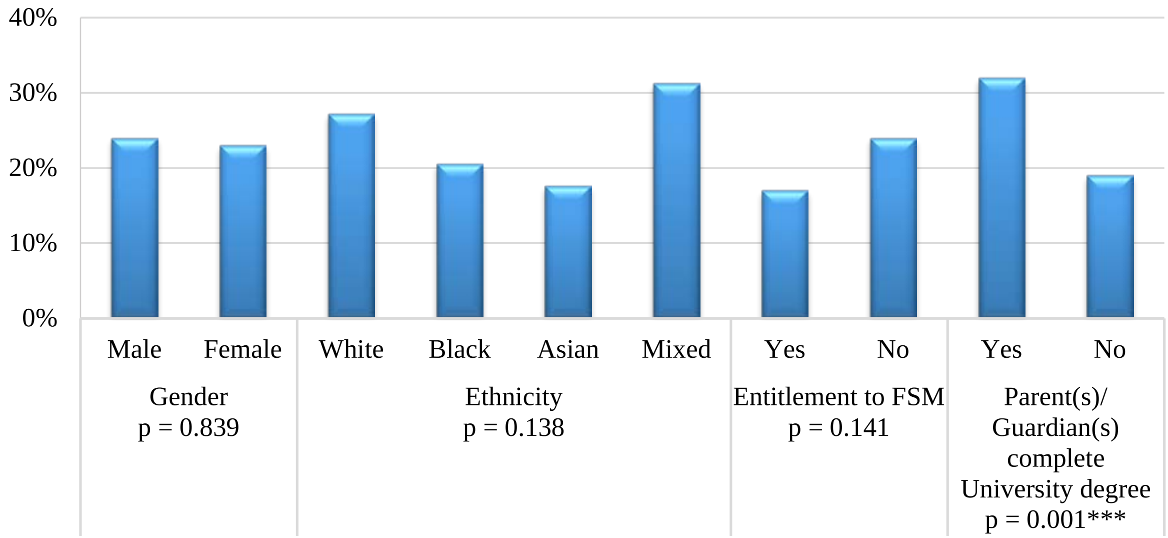

Figure 6.4: Student participation in STEM activities dependent on gender, ethnicity and socio-economic background, and; Key: * $p<0.05$; ** $p<0.01$; *** $p<0.001$

Figure 6.4 shows 24% of male students in the sample had engaged in outreach activities and of the female students it was 23%, and no statistical evidence for an association to suggest differences in participation rate between genders was found ($p>0.05$, chi-squared test). Despite the lower level of involvement from Black and Asian students and of those entitled to FSM participating in STEM outreach activities, the findings overall reflect promising efforts made by outreach. This is because no significant difference between those students' responses was found ($p>0.05$ for both groups, chi-squared tests). However, those students whose parents had completed a university degree were statistically more likely to be involved in STEM outreach events than the other students ($p=0.001$, chi-squared test).

The association of families and "science capital" with students' awareness and aspiration to pursue a science related career have been detailed by many studies (Archer 2013; Zecharia et al. 2014). The studies showed that families with low "science capital" are more likely to limit a student's horizon and aspiration to follow a career in science, and these difficulties also seem to appear to be connected with engaging students in STEM outreach.

Currently, Higher Education Institutions follow an access agreement, which states their approach of ensuring every student is given an equal opportunity to attend their university (OFFA 2016). Several STEM outreach initiatives have been designed to support universities fair access mission and to improve widening participation within universities for STEM related degrees (for example Cambridge Science Festival) (Tang 2011).

As a result, every university is trying to maintain their efforts of engaging and recruiting students from lower socio-economic groups and mature or part-time students (CaSe 2014). Although they all have the same purpose of inspiring those target groups, they each follow their own practise, and thus at present there is a varied approach amongst the different Higher Education Institutions towards improving the number of disadvantaged students targeted. Although there is variation in their approach, the overall picture is positive as collectively there is assurance that efforts are made towards giving every student an equal opportunity to attend university (DfE 2016; HEFCE 2006).

A key purpose of STEM outreach is to develop and influence students' knowledge and aspiration towards STEM subjects and careers (Finegold 2011). Therefore, in order to understand the impact of outreach activities, details of students involvement and experience is presented below in Figure 6.5.

Overall, Figure 6.5 displays a varied picture as it suggests students' experience in outreach has been fairly enjoyable and contributed towards making a difference to raising their awareness and understanding in STEM subjects. Though it seems the results are perhaps responsive to the age of this group, as the focus of outreach may not always relate to further studying STEM subjects and career aspiration, but rather at developing their general knowledge and awareness of STEM. This supports teachers (see Figure 5.1) and practitioners (see Figure 4.1) views; that the target year group is based on the intention of the activity.

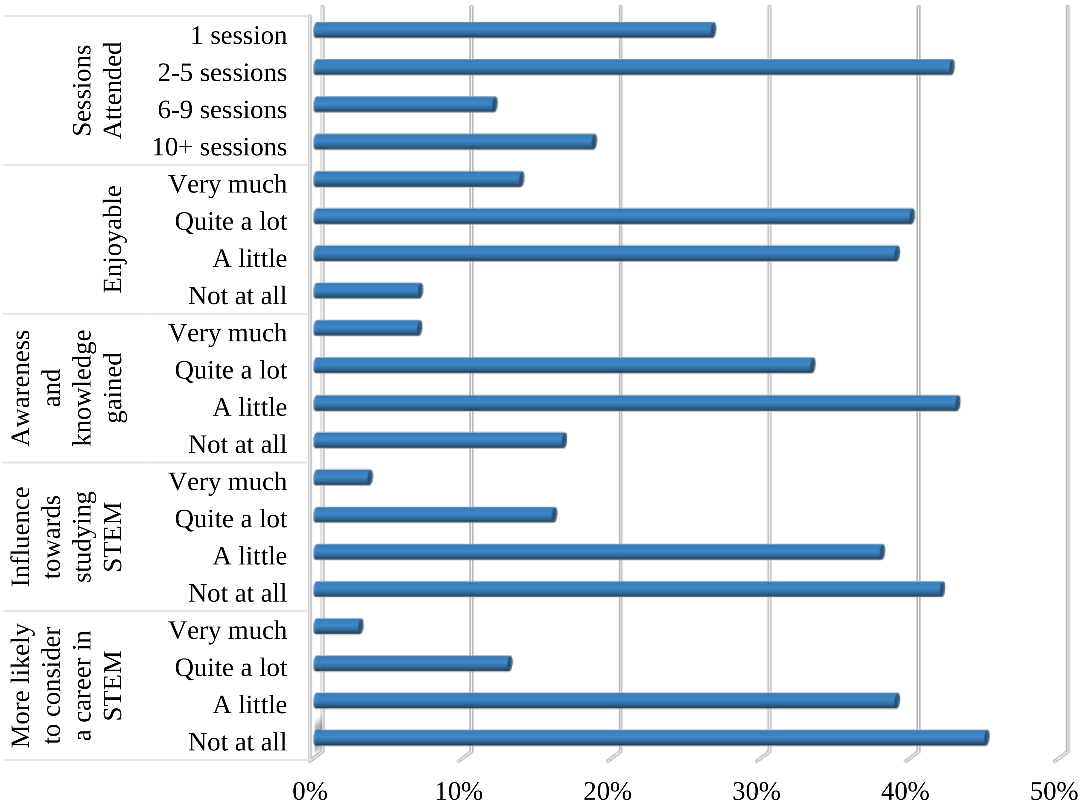

Figure 6.5: Impact of STEM outreach activities

In order to further understand the findings illustrated in Figure 6.5, the Spearman's rank correlation coefficient has been calculated for each of the above variables (see Table 6.3).

Correlations

			Sessions attended	Enjoyment	Awareness and knowledge	Influence towards studying STEM	More likely to consider a career in STEM
Spearman's rho	Sessions attended	Correlation Coefficient	1.000	0.211	0.213	0.145	0.163
		Sig. (2-tailed)	.	0.013*	0.012*	0.099	0.060
		N	145	138	137	131	134
	Enjoyment	Correlation Coefficient		1.000	0.574	0.419	0.404
		Sig. (2-tailed)		.	<0.001***	<0.001***	<0.001***
		N		140	138	132	135
	Awareness and knowledge	Correlation Coefficient			1.000	0.570	0.498
		Sig. (2-tailed)			.	<0.001***	<0.001***
		N			139	133	136
	Influence towards studying STEM	Correlation Coefficient				1.000	0.610
		Sig. (2-tailed)				.	<0.001***
		N				133	133
	More likely to consider a career in STEM	Correlation Coefficient					1.000
		Sig. (2-tailed)					.
		N					136

Table 6.3: Spearman's rank correlation coefficient, and; Key: * p<0.05; ** p<0.01; *** p<0.001

Mainly, across all variables, the results indicate a significant evidence of a positively correlated association. It appears that the more likely students were to consider a STEM career, the more enjoyable they found the activities ($p<0.001$, Spearman's rank correlation). In addition, a significant evidence of a positively correlated relationship between the number of sessions attended with how enjoyable and how much they gained from learning about STEM subjects was also found ($p=0.013$ and 0.012 respectively, Spearman's rank correlation). This relationship suggests two key possibilities, one of which is the association between attending a higher number of sessions in effect led the students responding to having greater enjoyment towards the activities. Or perhaps because a student is enjoying STEM they have agreed to attend more activities, and so this depends on whether the number of activities a student attends is in their control or not.

According to a recent study conducted by Archer (2013), one-off events are perhaps not the ideal approach for making a difference to students' future career choices. This also supports research by Laursen et al. (2007), who state that "society cannot rely on a single event to inspire a future scientist, but it must provide a range of opportunities for excellent science education, in school and outside it". However the results from this current study does not show a statistically significant correlation between number of sessions attended and influence on studying STEM subjects or more likely to consider a STEM career. This was approaching significant ($p=0.060$, Spearman's rank correlation) and had a small sample size. This suggests that just giving students more events is not likely to improve matters.

Following from the above analysis, based on the details the students provided on their STEM outreach experience, the statistical differences between the groups' gender and ethnicity has been investigated (see Table 6.5). By scoring the ordinal responses, the key shown in Table 6.4 (where a high value indicates a greater impact of STEM outreach) was used to calculate the median and the p-value for each group. For each variable, a different statistical test was used: a Mann-Whitney U test explored gender differences as this had two categories assigned (male and female) and a Kruskal Wallis test was used to test for ethnicity differences as this had more than two categories assigned. This key has also been used to calculate statistical differences in the median in the later analysis.

Although the p-values are based on testing the medians, the mean has also been shown in Table 6.5 i.e. median (mean) to help identify key differences between the two groups (gender and ethnicity) and students' responses to the six questions shown below. During a non-parametric analysis the differences between the means are not being tested. Jamieson (2004) explains that despite converting ordinal (likert) scale responses to numerical values, the intervals between the values cannot be presumed equal. Thus, for ordinal data sets the mean may be inappropriate and should not be used to describe the statistical differences, rather the whole distribution of responses is compared. She further states that the technique of treating ordinal scales as interval scales is highly controversial and has its limitations, though authors such as Blaikie (2003) address how often many authors do not consider this and treat it as an interval-level measurement. For the current study, the non-parametric tests compare medians and calculations involving ranks are used, and thus the mean values are only presented to support the interpretation of results.

Question	**Key**
Sessions attended:	1 = 1 session; 2 = 2-5 session; 3 = 6-10 sessions; 4 = 10+ sessions
Enjoyment:	1 = Not at all; 2 = A little; 3 = Quite a bit; 4 = Very much
Awareness and knowledge:	1 = Not at all; 2 = A little; 3 = Quite a bit; 4 = Very much
Influence towards studying STEM:	1 = Not at all; 2 = A little; 3 = Quite a bit; 4 = Very much
Consider a career in STEM:	1 = Not at all; 2 = A little; 3 = Quite a bit; 4 = Very much

Table 6.4: Scoring of each ordinal-scaled question

	Gender			Ethnicity				
	Male	Female	p-value	White	Black	Asian	Mixed	p-value
Sessions attended	2.0 (2.5)	2.0 (2.0)	0.006**	2.0 (2.2)	2.0 (1.7)	3.0 (2.5)	2.0 (1.9)	0.247
Enjoyment	3.0 (2.8)	2.0 (2.5)	0.014*	3.0 (2.6)	2.0 (2.6)	3.0 (2.9)	2.0 (2.3)	0.372
Awareness and knowledge	2.0 (2.4)	2.0 (2.2)	0.174	2.0 (2.2)	3.0 (3.0)	3.0 (2.6)	2.5 (2.2)	0.018*
Influence towards studying STEM	2.0 (2.0)	2.0 (1.7)	0.095	2.0 (1.7)	2.0 (2.0)	2.0 (2.1)	2.0 (1.8)	0.317
More likely to consider a career in STEM	2.0 (1.8)	1.0 (1.6)	0.139	1.0 (1.6)	1.0 (2.1)	2.0 (2.2)	2.0 (1.8)	0.015*

Table 6.5: The median (mean) of students from different gender and ethnicity based on the details provided on their impact of STEM outreach, and; Key: * $p<0.05$; ** $p<0.01$; *** $p<0.001$

The results identify a key concern. They suggest the girls, on average, were involved in significantly fewer sessions and the activities were not as enjoyable for them as they were for the boys (p=0.006 and 0.014 respectively, Mann-Whitney U tests). A study by Mujtaba and Reiss (2013) explored factors that influence girls of age 15 to study physics and reported a finding by Stewart (1998) who found enjoyment played a significant role towards attracting girls to study physics beyond GCSE (more than the boys).

The results from Table 6.5 also indicate that students from White and Black ethnic backgrounds expressed no more change in their likelihood of seeking a STEM career after engaging in STEM outreach. Whereas students from Mixed and Asian backgrounds (p=0.015, Kruskal Wallis test) has indicated change. A significant difference was also detected in their awareness and knowledge when analysing by ethnicity, with greater awareness and knowledge shown in Black and Asian students. As mentioned earlier (see Table 6.2) the Black students had the highest proportion of parents with degrees (therefore probably more science capital). It was also highlighted in the literature review (Chapter 2) that Asian ethnicity is over represented in the STEM workforce.

6.2.2 Key decisions of GCSE students

The GCSE students had already made a formal decision over the subjects they are studying as their Key Stage 4 options and are approaching another crucial stage to select their post-16 options (Broughton 2013). These decisions, made by young adults, are of great importance as they have the potential to shape their future career and job prospects. Such decisions are highly likely to affect whether or not they move towards becoming a graduate in STEM. After completing Key Stage 4, there are numerous types of courses and qualifications to choose from. Figure 6.6 illustrates what students from this sample were considering doing after their GCSEs, and some participants provided more than one response.

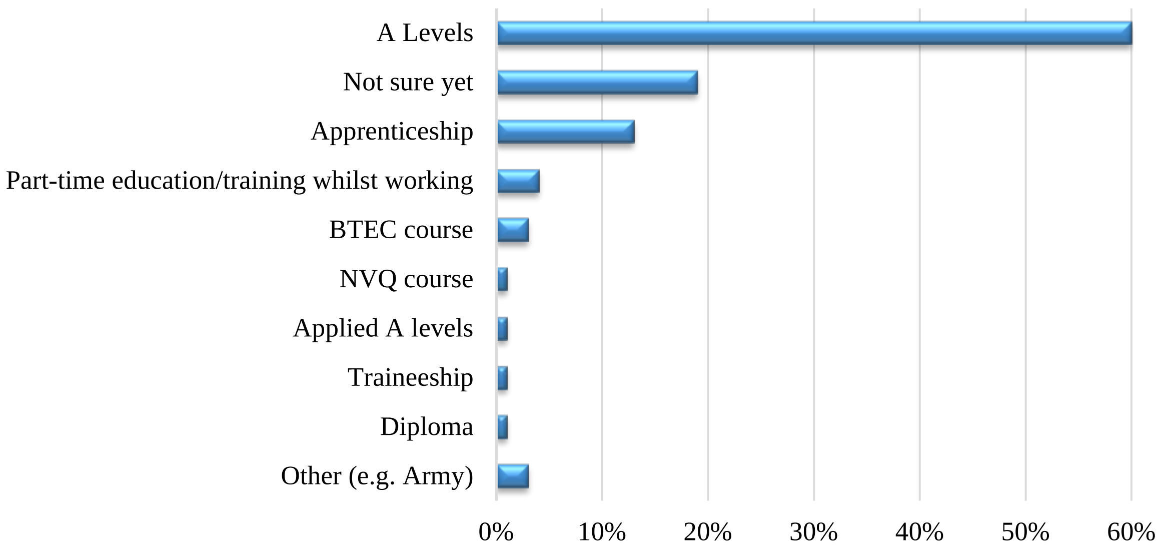

Figure 6.6: Post-16 options considered by GCSE students

The quality and accessibility of apprenticeships, as well as the low take up and awareness of this as an alternative route to a STEM career, are identified problems (Wolf 2011; Adecco 2015). Reflecting the results from this current study, 13% of students in this sample were considering an apprenticeship and 60% were considering taking the traditional academic route of A levels. Further, many studies have highlighted the drawbacks of providing poor careers advice to students of all ages and, therefore, limiting their vision and understanding on the various routes beyond GCSE (Sainsbury 2007; Holman and Finegold 2010; The Royal Society 2014a). This problem may account for the results from this sample illustrated in Figure 6.6. When asked what they were planning to do after completing their GCSEs 19% responded with “not sure yet”, suggesting that some may be indecisive on their decision. However, of those that said they were unsure, half the students indicated that they received no careers advice and 5% selected multiple options, providing a rough inclination of what they may do after their GCSEs.

Whether or not young people obtained advice to support their key decision was further explored, resulting in mixed responses. The study found 52% of students responded with a “yes” to obtaining advice to support their understanding of the available post-16 options and the remaining 48% said “no”. Those who were made aware stated in which school year(s) this occurred, and multiple options were reported and for majority this occurred in year 9 (44%) or year 10 (57%) (see Figure 6.7).

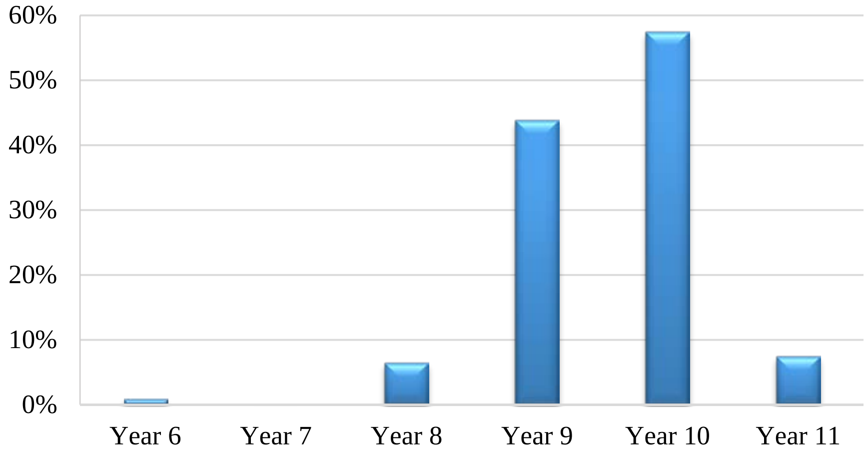

Figure 6.7: School year when GCSE students were made aware of the available post-16 options

Below is a series of contingency tables with analysis of results based on the proportion of those who mentioned A Levels, apprenticeships or were uncertain towards their future course choices. These analysis explore the relationship between a student's responses to factors that are highly likely to influence their decision (Blenkinsop et al. 2006). As the students chose multiple responses, an independent analysis using a chi-squared test (X^2) and Fisher's exact test (FE) was conducted in order to understand the differences between each association, i.e. gender and those choosing A levels (see Table 6.6).

Gender				
	Male	Female	p-value	Test
A Levels	52%	66%	0.001***	X^2
Apprenticeship	20%	7%	<0.001***	X^2
Not sure	22%	16%	0.077	X^2

Ethnic Background						
	White	Black	Asian	Mixed	p-value	Test
A Levels	56%	79%	72%	58%	<0.001***	X^2
Apprenticeship	14%	9%	10%	9%	0.559	FE
Not sure	20%	9%	14%	18%	0.140	FE

Parent/Guardian completed a university degree				
	Yes	No	p-value	Test
A Levels	71%	56%	<0.001***	X^2
Apprenticeship	11%	12%	0.719	X^2
Not sure	12%	21%	0.003**	X^2

Participation in STEM outreach activities				
	Yes	No	p-value	Test
A Levels	74%	56%	<0.001***	X^2
Apprenticeship	8%	15%	0.024*	X^2
Not sure	12%	21%	0.013*	X^2

Advice obtained towards understanding post-16 options				
	Yes	No	p-value	Test
A Levels	61%	61%	0.985	FE
Apprenticeship	16%	9%	0.007**	X^2
Not sure	16%	21%	0.087	X^2

Table 6.6: The association between key factors and students post-16 choices, and Key: * p<0.05; ** p<0.01; *** p<0.001

The results show that there is a very strong significant relationship between gender and students' post-16 choices (p=0.001 and <0.001 respectively, chi-squared tests). It was found that more girls were interested in choosing an A level route than boys (66% of girls compared to 52% of boys) and only 7% of girls compared to 20% of boys were considering an apprenticeship route.

A study conducted by DfES (2007) explored the differences between gender and pupils' education in England and found girls were more likely than boys both to stay on in full-time education at age 16 and enter for an A level qualification. Nevertheless, Joint Council for Qualifications (JCQ) has shown that within the separate qualifications the gender gaps remain for particular STEM subjects with more boys than girls taking mathematics and science A levels. Their published A level entrant numbers for 2015 quantified subjects such as A level Computing, Physics and Mathematics (Further) as still consisting a higher proportion of boys than girls (e.g. of the total number of students that were entered for A level Computing, 92% were male students and 8% were female students) (Arnett and Bengtsson 2015).

A very strong significant difference was found across the responses from the ethnic groups about selecting A levels (p<0.001, chi-squared test). The sample suggested students of BME origin were more inclined towards choosing the traditional academic route, whereas a greater proportion of young people from a White ethnic background were considering taking up the apprenticeship route instead. This perhaps reflects the sample as a greater proportion of Black students had parents with a degree than the other ethnic groups (see Table 6.2). A similar view was shown by the Youth Cohort Study (2008b), that found a greater proportion of young Black and Asian students tend to remain in full-time education compared to White students. Payne (2003a) suggested that lower attainment grades at GCSE could be the reason for differences in qualification choices across gender and ethnicity. She suggested poor results are an important reason for influencing more males and more White ethnic students to choose vocational routes instead of A levels.

Many studies have highlighted the impact a parent's education background has on the path a young student takes in her/his education journey (Payne 2003; Rennison et al. 2005; Kirchner et al. 2015). This is aligned with the data in this study which showed very strong significant evidence for an association between those considering A levels and whether or not a parent/guardian had completed a university degree ($p<0.001$, chi-squared test). Similarly, significant evidence emerged to suggest greater certainty amongst those students whose parent/guardian had completed a university degree. Overall, fewer students (12%) stated they were unsure on their post-16 decision than amongst those students whose parent/guardian had not completed a university degree (21%) ($p=0.003$, chi-squared test).

The results also show that the attractiveness of the apprenticeship route almost doubles when students receive guidance ($p=0.007$, chi-squared test), suggesting they possibly did not know what apprenticeships were until they received guidance. The Women and Work Commission (2006) support this view as they signify the importance of providing young women especially with high quality careers guidance as their recommendation to encourage them towards considering non-traditional roles (Prosser 2006).

A significant relationship was also shown between student's key decisions and participation in STEM outreach ($p<0.05$, chi-squared tests). The findings suggest that participation in STEM outreach events may have reduced students' uncertainty, as of those who had engaged in outreach events, fewer students were uncertain on their post-16 decisions (12%) than those who had not (21%). It also seems that it has resulted in positive decisions for A levels, as of those students who had taken part in a STEM outreach activity, 74% were considering a traditional academic route compared with just 56% of those that had not ($p<0.001$, chi-squared test). An impact on apprenticeships is also shown ($p=0.025$, chi-squared test). This raises a few possibilities: one perhaps is that those who participate in STEM outreach believe they need A levels to get a STEM degree or that those who want to take up A levels do STEM outreach to support their decision on their post-16 decision of taking up science A levels. Further, it suggests that outreach practitioners are possibly biased towards universities rather than industry, therefore they focus on the A level/graduate route rather than on apprenticeships.

However, this route may not be suitable for all pupils. Therefore, these findings suggest that STEM outreach activities perhaps need to promote apprenticeships as the proportion of students considering an apprenticeship almost halved for those undertaking STEM outreach (of those engaged in STEM outreach, 15% were considering an apprenticeship compared to 8%).

6.2.3 Key influences of GCSE students

A study by Blenkinsop et al. (2006) explored how young people of ages 14 and 16 make their choices, and highlighted factors that have a strong potential to make a difference in how these decisions are made. They further outlined the role of a school as well as other factors (i.e. parents, family members) influencing this decision.

For this current study, several students selected more than one major source of influence, illustrating how this is not a one-step process and that over the years a range of factors has perhaps steered the students' decision. The responses provided by the students are illustrated below in Figure 6.8.

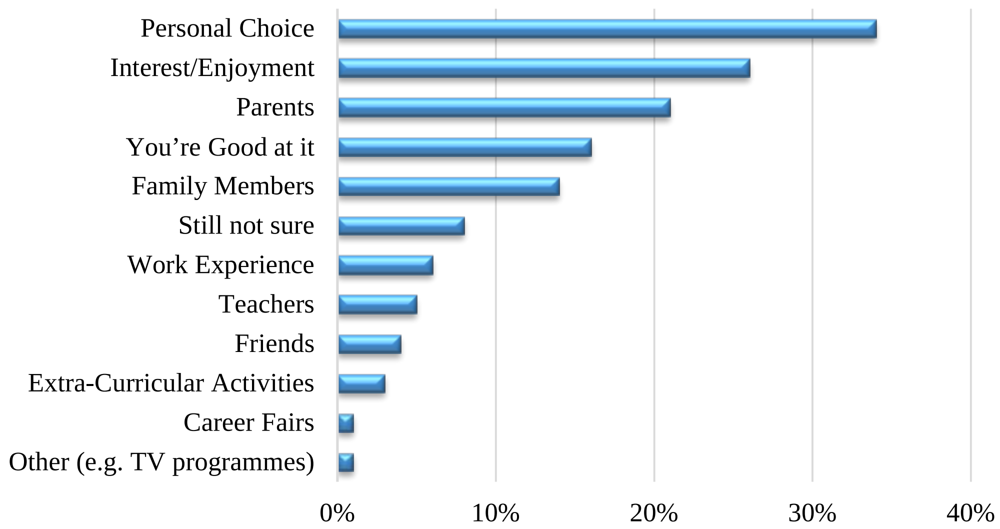

Figure 6.8: Factors influencing GCSE students towards making key post-16 decisions

Five key factors were identified as the most frequent sources of influence, namely personal choice, interest and/or enjoyment, parents, their ability, and family members. Of those variables that were most frequent, the responses have been analysed according to gender and ethnicity using a chi-squared test (X^2) and Fisher's exact test (FE) (see Table 6.7).

	Gender			Ethnicity					
	Male	Female	p-value	White	Black	Asian	Mixed	p-value	Test
Personal Choice	28%	38%	0.007**	35%	29%	34%	31%	0.895	X^2
Interest/ Enjoyment	25%	27%	0.601	28%	21%	25%	19%	0.505	X^2
Parents	20%	21%	0.789	17%	32%	26%	25%	0.038*	X^2
You're Good at it	18%	15%	0.258	15%	21%	16%	19%	0.840	FE
Family Members	17%	11%	0.025*	13%	18%	15%	9%	0.731	FE

Table 6.7: The association between factors influencing post-16 decisions with gender and ethnicity, and; Key: * $p<0.05$; ** $p<0.01$; *** $p<0.001$

Warrington, Younger and Williams (2000) studied factors that affected boys and girls towards their GCSE attainment and identified attitudes and image as a concern. A key finding emerged from interviews with students and teachers and lesson observations. They found "a common pattern of most girls, at least by year 10, realising the value of achieving as good a set of GCSE grades as possible and focusing quite seriously on this goal and beyond". They further quoted a comment made by a Deputy Head Teacher in a comprehensive school who said "girls are far better at learning independently, taking decisions about what they are doing themselves". Girls in this current study appeared to have a stronger mindset too, as they were significantly more inclined towards choosing their post-16 choices due to personal choice (38%) than were the boys (28%) (p=0.007, chi-squared test).

Whereas, family members who have been recognised as an influential factor when students of this age are making course decisions (Blenkinsop et al. 2006), appeared to have a significantly greater influence on the boys (17%) than on the girls (11%) (p=0.025, chi-square test). Furthermore, evidence suggested parents played a significantly greater influential role towards young Black pupils (32%) when making course decisions in comparison to those of White, Asian and Mixed ethnic pupils (p=0.038, chi-squared test). A *"Longitudinal Study of Young People in England"* (LSYPE) in 2007 presented similar views and showed parental involvement and educational aspirations of young Black and ethnic groups were a lot greater in comparison to pupils from a White ethnic background (DCSF 2008b).

6.2.4 Enjoyment towards STEM subjects of GCSE students

GCSE students were questioned on whether they enjoyed STEM subjects. Allowing them to choose more than one subject, the percentage of students that responded to enjoying each subject is illustrated below in Figure 6.9.

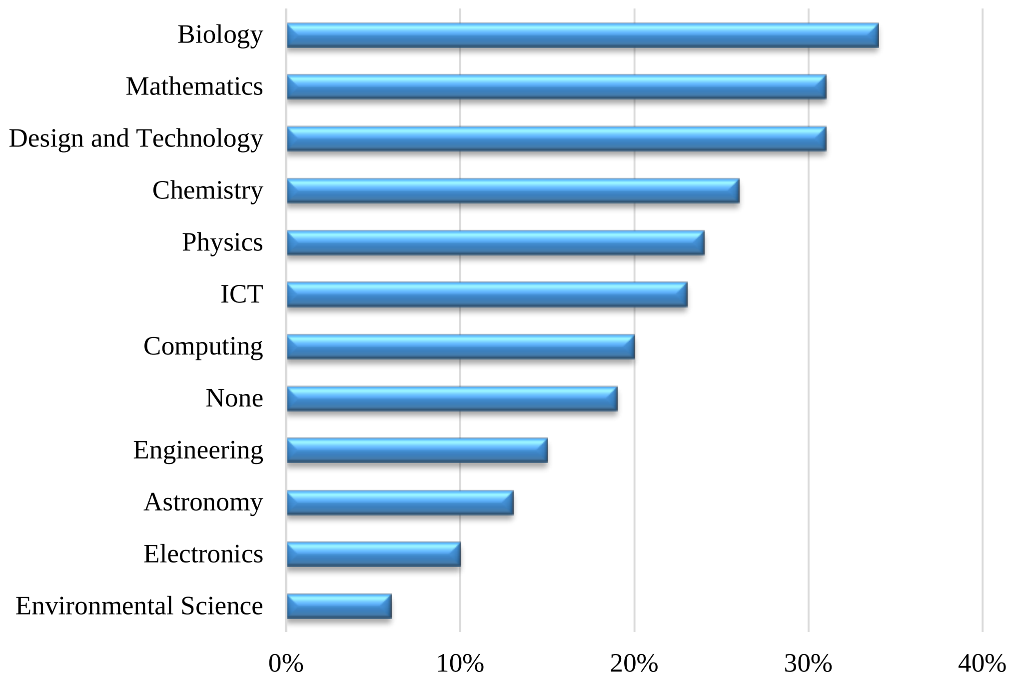

Figure 6.9: The proportion of students that found STEM subjects enjoyable

The above results are alarming as from the most popular STEM subjects, only a third of GCSE students enjoy biology (34%), and slightly fewer enjoy mathematics (31%) and design and technology (31%). As we go down Figure 6.9, it also appears that one in five students (19%) indicated they did not enjoy any of the eleven named STEM subjects and, therefore, chose "none" as their response to this question. Further, the results show that even fewer enjoyed subjects such as engineering (15%) and environmental science (6%), though it is acknowledged that there is a great possibility the students do not know what these are and have not had the opportunity for these subjects to be taught or explained to them. Thus, a key difference is observed, as although everyone provided a response to these questions, they were not answering it from the same position: everyone who answered this question have been taught mathematics, science, design and technology, ICT and/or computing STEM subjects, though perhaps not the other STEM subjects. Despite this difference, the findings are of great concern, suggesting that less than one in three students enjoy compulsory STEM subjects taught at school. Students who have not studied a particular subject may have left it blank.

Below for each subject, an association between enjoyment and differences in student responses by gender, ethnicity and whether or not they participated in STEM outreach is investigated using a chi-squared test. The p-values are presented indicating whether the association between the variables is statistically significant or not. Table 6.8 also displays the direction of the association for gender (male/female) and participation in STEM outreach (yes/no).

The results suggest there is very strong evidence that gender is associated with enjoying STEM subjects. In this sample, biology was the only subject that was enjoyed by considerably more girls than boys, and as for the remaining significant associations, boys showed more enjoyment than girls in the majority of the STEM subjects ($p<0.05$, chi-squared tests). This was also reflected in design and technology, astronomy, and environmental science, though the differences were statistically not significant ($p>0.05$, chi-squared tests). Nevertheless to support these findings further, the girls were significantly more likely to choose the "none" response than the boys ($p=0.002$, chi-squared test).

Subject	Gender		STEM outreach		Ethnicity
Mathematics	0.011*	m>f	<0.001***	y>n	0.015*
Biology	0.001***	f>m	0.008**	y>n	0.014*
Physics	<0.001***	m>f	<0.001***	y>n	0.828
Chemistry	<0.001***	m>f	<0.001***	y>n	0.998
ICT	<0.001***	m>f	0.407	n>y	0.308
Computing	<0.001***	m>f	0.241	y>n	0.072
Engineering	<0.001***	m>f	0.005**	y>n	0.402
Design and Technology	0.343	m>f	<0.001***	y>n	0.020*
Astronomy	0.488	m>f	0.165	y>n	0.826
Electronics	<0.001***	m>f	0.001***	y>n	0.504
Environmental Science	0.558	m>f	0.077	y>n	0.316
None of the STEM subjects	0.002**	f>m	0.002**	n<y	0.916

Table 6.8: Statistical differences based on enjoying each STEM subject and students from different gender, ethnicity and STEM outreach participation, and; Key: * $p<0.05$; ** $p<0.01$; *** $p<0.001$

A weak association between students' engagement in STEM outreach and enjoyment in many of the STEM subjects was also found ($p<0.05$, chi-squared tests). The results showed that of those who participated in STEM outreach ("yes"), significantly fewer students responded to enjoying "none" of the STEM subjects (22%) and of those that did take part it was 10% ($p=0.002$, chi-squared test). This analysis suggests two key possibilities: because the students enjoy these subjects they are more likely to engage in outreach activities, or that due to their engagement in STEM outreach they are enjoying the subjects.

An association with ethnicity was only found for mathematics, biology, and design and technology, and this was not as strong as the gender effects. Greater proportions of Asian students enjoyed mathematics (41%), whereas White students least enjoyed this subject (27%). On the other hand, a larger proportion of Black ethnic students (59%) than the other ethnic groups enjoyed biology, but when asked about enjoying design and technology the percentage was only 15%. As a result, a significant difference between ethnicities was detected in their enjoyment of STEM subjects ($p<0.05$, chi-squared tests).

6.2.5 Level of understanding of STEM subjects of GCSE students

Another area investigated was students' level of understanding of what the subject is, which included mathematics, biology, physics, chemistry, computer science, and engineering (see Figure 6.10).

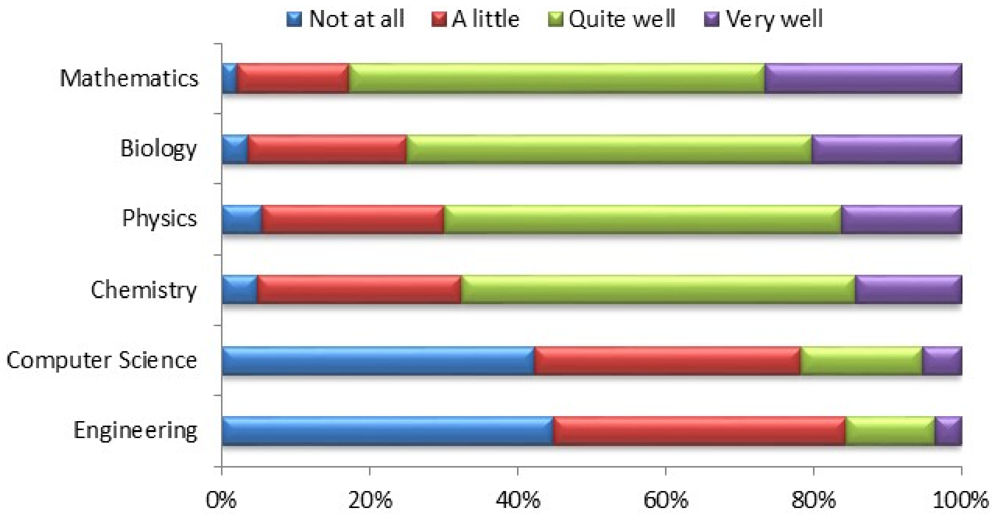

Figure 6.10: Level of understanding of STEM subjects

The question might have been interpreted differently by different participants (see Appendix D, question 28), implying the students may have responded about their understanding of how to do the subject (i.e. students' perception of their ability and skills in the subject) rather than understanding what the subject entails. Thus, the response provided could be measuring either of the two things. Despite the differences in interpretation and the potential ambiguity and difficulty in the analysis of the question, important conclusions can still be drawn from this analysis. This is because the two are not completely independent i.e. you cannot do engineering if you do not know what engineering is. This also applies for the A level and STEM undergraduate student data.

Overall, a large proportion of students appeared to have a satisfactory level of understanding of four of the six subjects; mathematics, physics, chemistry, and biology; whereas a substantial proportion of GCSE students felt their understanding of computer science and engineering was “not at all” (42% and 45% respectively). These findings reflect the national curriculum at the time of the survey. Mathematics and science were (and still are) an integral part of the compulsory STEM subjects taught during Key Stage 4, whereas computer science and engineering were not. At the time the survey was conducted very few schools offered computer science/computing at GCSE level, but all schools had ICT as part of the curriculum (BBC News 2015).

Table 6.9 displays the survey sample difference in gender, ethnicity, and whether or not a student had participated in a STEM outreach activity towards their understanding of what STEM subjects entail. By scoring the ordinal responses, the key shown below Table 6.9 was used to calculate the median for each group (where a high value indicates a better understanding of what the subject is). Appropriate statistical tests, Mann-Whitney U test (gender and participation in STEM outreach) and Kruskal Wallis test (ethnicity), were used and the p-values based on the median for each group were calculated.

	Gender			Ethnicity					Participation in STEM outreach		
	Male	Female	p-value	White	Black	Asian	Mixed	p-value	Yes	No	p-value
Mathematics	3.0 (3.1)	3.0 (3.0)	0.045*	3.0 (3.0)	3.0 (3.2)	3.0 (3.2)	3.0 (3.2)	0.030*	3.0 (3.2)	3.0 (3.0)	0.004**
Biology	3.0 (2.9)	3.0 (2.9)	0.341	3.0 (2.8)	3.0 (3.2)	3.0 (3.1)	3.0 (2.9)	0.002**	3.0 (3.0)	3.0 (2.9)	0.163
Physics	3.0 (2.9)	3.0 (2.7)	<0.001***	3.0 (2.8)	3.0 (2.7)	3.0 (2.9)	3.0 (2.9)	0.297	3.0 (3.0)	3.0 (2.8)	0.009**
Chemistry	3.0 (2.8)	3.0 (2.7)	0.074	3.0 (2.7)	3.0 (2.9)	3.0 (2.9)	3.0 (2.9)	0.028*	3.0 (2.9)	3.0 (2.7)	0.047*
Computer Science	2.0 (2.1)	1.0 (1.6)	<0.001***	2.0 (1.9)	2.0 (1.8)	2.0 (1.9)	1.0 (1.7)	0.593	2.0 (2.1)	2.0 (1.8)	<0.001***
Engineering	2.0 (2.0)	1.0 (1.5)	<0.001***	2.0 (1.8)	2.0 (1.8)	2.0 (1.7)	1.0 (1.6)	0.692	2.0 (2.0)	2.0 (1.7)	<0.001***

Table 6.9: The median (mean) of students from different gender, ethnicity and participation in STEM activities, and; Key: 1 = Not at all; 2 = A little; 3 = Quite a bit; 4 = Very much, and; Key: * p<0.05; ** p<0.01; *** p<0.001

After taking gender, ethnicity and differences in outreach participation into account, a better understanding of how students perceive their knowledge in certain STEM subjects emerges. The boys expressed a greater understanding of the subjects engineering, computer science and physics than the girls ($p<0.001$ for all three subjects, Mann-Whitney U tests). Hence, for those subjects the median (mean) value for male is greater or equal to the median (mean) value for female and it appears that, on average, the girls felt their understanding of engineering and computer science in particular to be almost non-existent. These findings confirm what has been observed in other studies, which have emphasised how girls limit their association and identity when it comes to engaging and demonstrating an interest in these subjects (Archer 2013; House of Commons Science and Technology Committee 2014; House of Lords Select Committee on Digital Skills 2015).

The findings also showed evidence for boys expressing a better understanding of mathematics than the girls, and this was significant but mildly so ($p=0.045$, Mann-Whitney U test). A statistically significant difference in the students responses based on ethnicities was also found, as on average White students had a lower understanding of mathematics ($p=0.030$, Kruskal Wallis test). This was also the case for the subjects chemistry and biology, as on average White students displayed less certainty on their understanding of those STEM subjects ($p=0.002$ and 0.028 respectively, Kruskal Wallis tests).

Many reviewers (Wynarczyk and Hale 2009; Finegold 2011; Parliamentary Office of Science and Technology 2011; Packard 2011; Mann and Oldknow 2012; Perkins 2013) have reinforced that the purpose and benefits of outreach are to impact and support students' attitude, preconceived ideas, behaviour, understanding, knowledge and confidence in their ability to "do" STEM subjects (Parliamentary Office of Science and Technology 2011).

The findings from my study convey a similar message and suggest there is sufficient evidence to support the view that engagement in STEM outreach activities can perhaps make a significant difference to students' perception of understanding of the STEM subjects. The students that were involved in STEM outreach appeared to understand engineering, computer science, mathematics and physics better than those that had not taken part in STEM activities ($p<0.001$, <0.001, 0.003 and 0.010 respectively, Mann-Whitney U tests), and for chemistry the difference was marginally significant ($p=0.049$, Mann-Whitney U test). For engineering and computer science, in particular, the difference was large, and as a result the statistical evidence suggested that those who had not participated in STEM outreach activities were more likely to provide a less positive response than those who had. Therefore, evidence suggests that those given the opportunity to experience STEM outreach felt they had a greater understanding of STEM subjects. Hence, the findings from this study emphasise the importance of involving students in STEM outreach activities, especially by age 16. Therefore, they are developing their knowledge and understanding in a wide range of subjects taught in school. They are also building an awareness of those subjects which are not taught in school.

6.2.6 Academic stages of understanding STEM careers of GCSE students

Another key agenda has been increasing the general awareness of STEM careers amongst students so that their ability to make an informed decision related to subject choices and career aspirations is enhanced (Finegold 2011; Mellors-Bourne, Connor and Jackson 2011). This current study aimed to investigate the differences in students' perception of when they understood the roles of STEM professionals in different specialist fields. The findings are illustrated in Figure 6.11.

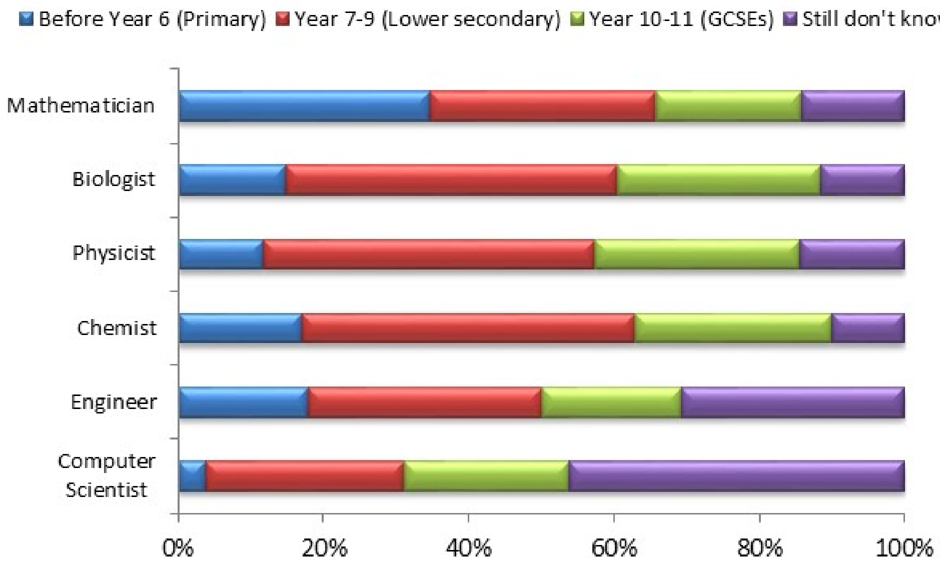

Figure 6.11: Academic stages of understanding STEM careers

Many studies (Mellors-Bourne, Connor and Jackson 2011; Atkins 2013; Zecharia et al. 2014; House of Lords Select Committee on Digital Skills 2015) have highlighted the lack of awareness that exists amongst young people, especially for engineering and computer science related jobs. This is also reflected in the results from this current study, as almost half of the students conveyed uncertainty towards understanding what computer scientists do (46%) and for engineers this was just under a third (31%). Further, it suggests the students are still disconnected and uninformed on a range of careers that are offered through STEM qualifications, and so limiting their post-16 choices as well as higher education and career aspiration in STEM. Thus, it is essential to ensure that students receive quality guidance and advice on subject and career choices before the age of 16 (Davies and Cox 2014).

The statistical difference in gender, ethnicity and whether or not a student participated in a STEM outreach activity with a students' academic stage of awareness on careers, has further been explored. Figures 6.12, 6.13 and 6.14 outline these differences. For each profession that was found significant with its independent variable, it has been noted by a key (* p<0.05, ** p<0.01, *** p<0.001).

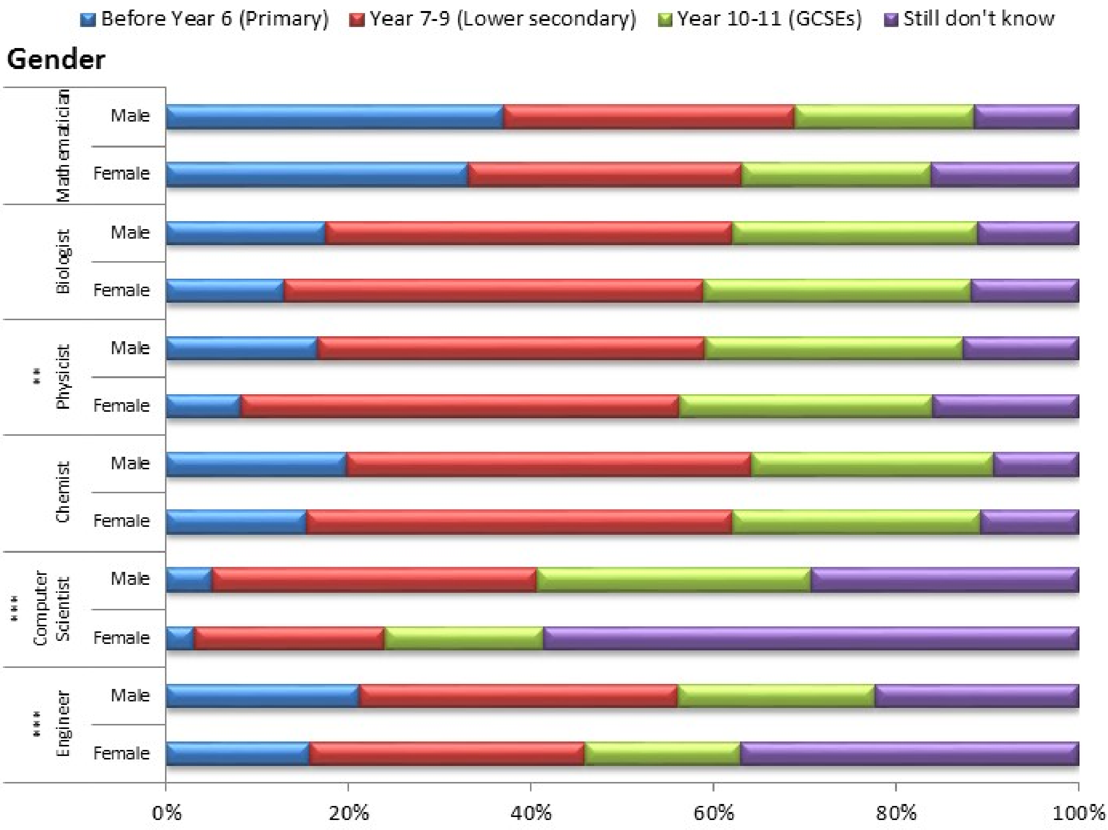

Figure 6.12: The association between students' academic stage of career awareness with gender

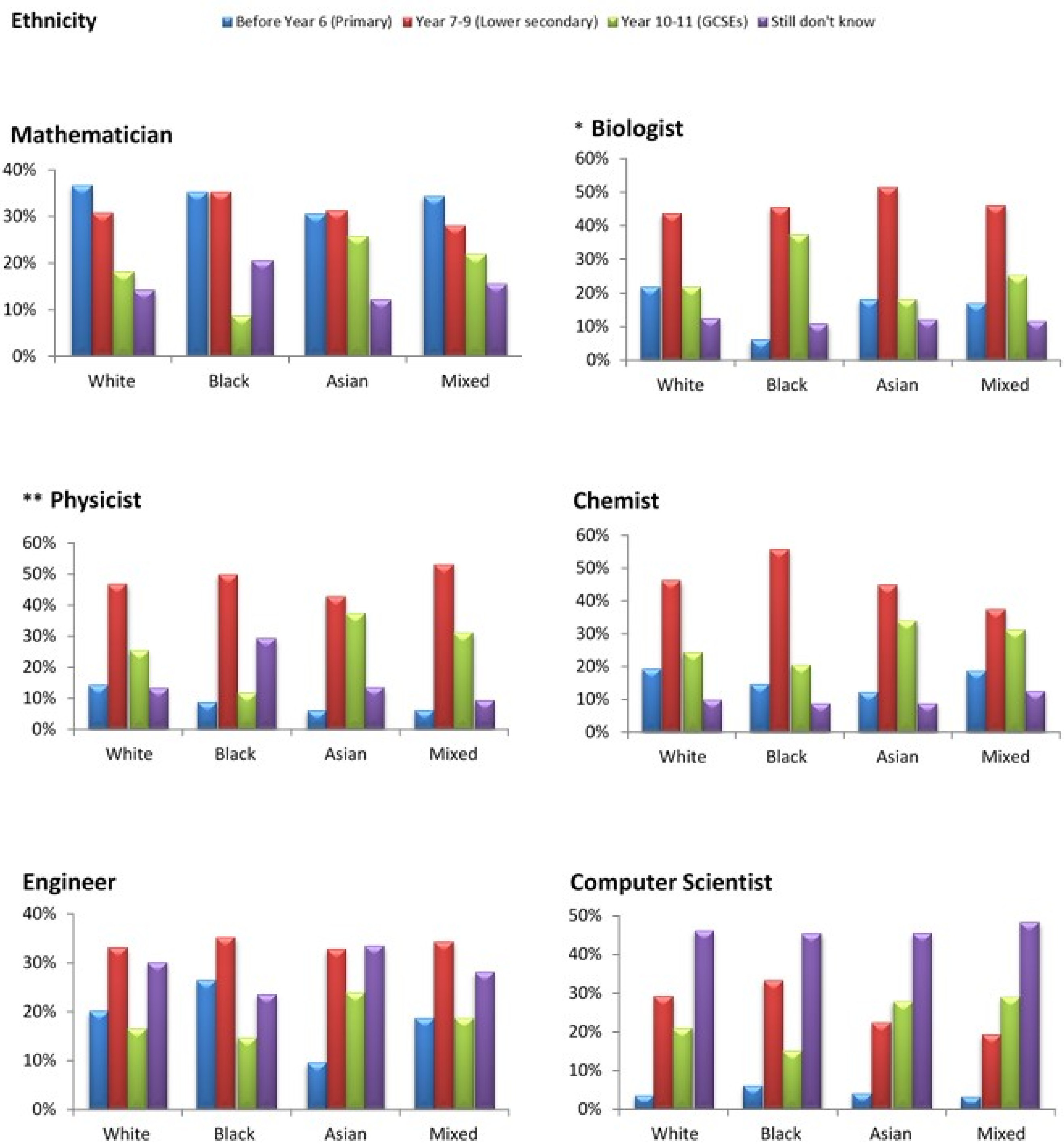

Figure 6.13: The association between students' academic stage of career awareness with ethnicity

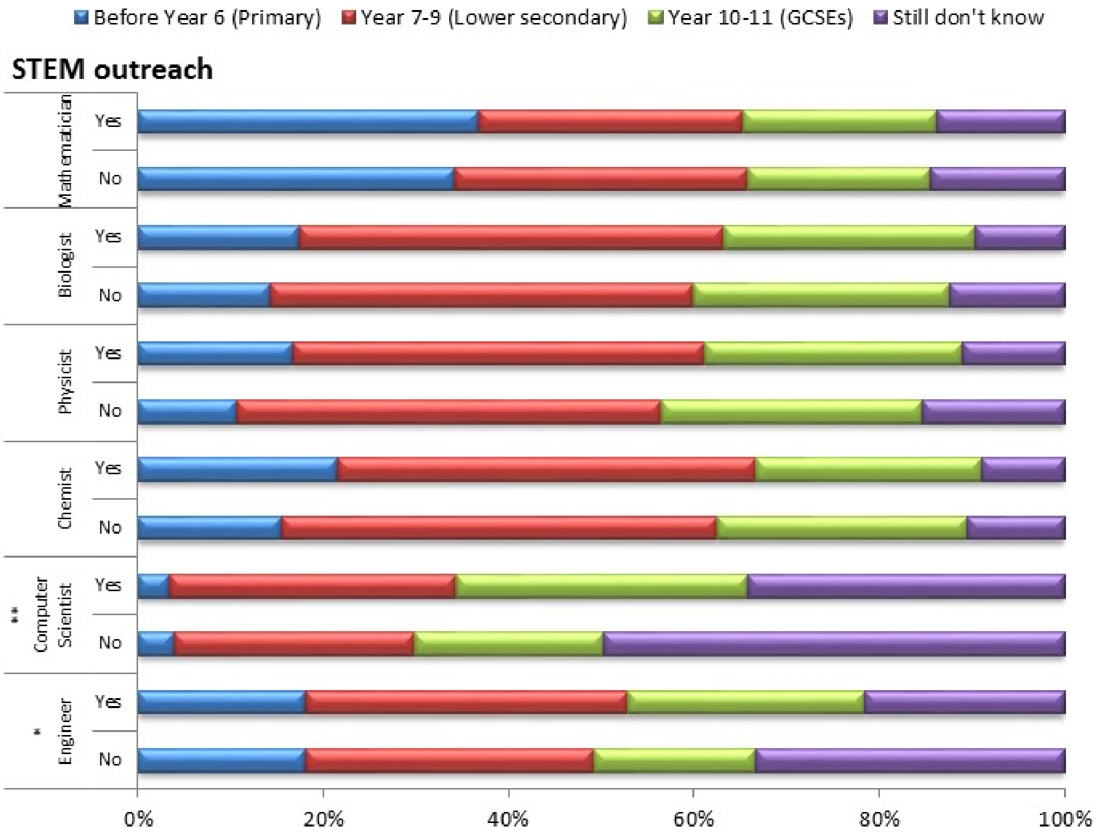

Figure 6.14: The association between students' academic stage of career awareness with participation in STEM activities

The results summarised in Table 6.10, display the p-values calculated from a chi-squared test and Fisher's exact test based on the association between students' academic stage of understanding STEM careers and the variables: gender, ethnicity and students engagement with STEM outreach.

Overall, the boys said they gained awareness of understanding of each of the STEM professionals earlier than the girls, and a statistically significant relationship was evident between gender and academic stages students understood the profession; physicist, computer scientist and engineer ($p=0.009$, <0.001 and 0.001 respectively, chi-squared tests). Over half the girls said they were unfamiliar with the range of careers from computer science, and a similar proportion of girls showed a lack of awareness of what engineers and physicists do, compared to lower proportion of boys.

	Mathematician	Biologist	Physicist	Chemist	Computer Scientist	Engineer
Gender	0.324	0.439	0.009**	0.528	<0.001***	0.001***
Ethnicity	0.503	0.036*	0.008*	0.405	0.623	0.176
STEM outreach	0.889	0.709	0.198	0.393	0.006**	0.026*

Table 6.10: Statistical differences based on the academic stage of understanding STEM careers and students from different gender, ethnicity and STEM outreach participation, and; Key: * p<0.05; ** p<0.01; *** p<0.001

These results correlate with findings from previous studies (Mellors-Bourne, Connor and Jackson 2011; Atkins 2013; Moody 2015; House of Lords Select Committee on Digital Skills 2015), which many have further described as an “image problem” with these professions. The view of these careers being for boys and not for girls has been seen as a major concern as it appears to affect girls’ desire to engage in post-16 STEM subjects. The male dominated roles within these professions present a serious deterrent to would-be female engineers and computer scientists. A study by Atkins (2013) involved interviews with female engineers. A key issue addressed was how, according to them, engineers were perceived by young females. Many respondents said that engineering is still seen as “a male career” and that it “involves fixing engines”. Further, in a report by Ofsted (2011), “*Girls’ career aspiration*” found girls especially were affected by the quality of careers advice given during school, towards making informed choices about courses and careers at post-16.

Evidence was found to suggest that the differences in responses from ethnic groups were statistically significant in their understanding of biologist and physicist (p=0.036 and 0.008 respectively, Fisher’s exact tests). A higher proportion of Black students showed uncertainty towards understanding what a physicist would do as a career. It also appears Black students become aware of what biologists do later in their academic years. The issue of engaging students from a Black origin in scientific related careers has been highlighted by Loke (2014), and how the lack of role models from scientific professions acts as a barrier for students from Black and ethnic minorities to engage in and aspire to such careers.

This sample also offered evidence to suggest that participating in STEM outreach positively influenced students' responses to this question. Those who participated in STEM activities were less inclined to state they "still did not know" what each of the STEM professionals do, compared to those who had not participated in outreach. When tested for significant differences, a very strong association was found between students' awareness of what computer scientists and engineers do and whether or not they had participated in STEM activities (p=0.006 and 0.026 respectively, chi-squared tests). These results again give emphasis to the importance of engaging students in extra-curricular STEM activities. Initially, students demonstrated the least awareness in careers related to computer science and engineering (see Figure 6.11) and in this instance, the evidence suggests that student participation in outreach has significantly improved their ability to state that they gain sufficient knowledge of these specific areas of STEM whilst at school. This supports the purpose of many outreach initiatives (Wynarczyk and Hale 2009; Parliamentary Office of Science and Technology 2011) as it appears participation in outreach has effectively made a difference in raising students' awareness of STEM careers, especially in the computer science and engineering field, before post-16 decisions are made.

6.3 A Level student sample

The A level student sample consisted of 465 students studying in years 12 and 13, and this data were collected through a questionnaire during the period May 2014 to November 2014 (see Appendix E). Of the sample, data from 207 students was collected from eight schools/colleges, and the remaining sample of 258 students was collected by the researcher attending six different types of events held at universities. Of the sample, 46% were male and 54% were female, and they were from a range of ethnic backgrounds. Nine students who gave their ethnicity as other have not been included in the analysis of student responses when overviewing statistical relationships across different ethnicities. The subjects studied at AS level were a combination of STEM and non-STEM subjects; STEM related subjects included AS Mathematics, Further Mathematics, Chemistry, Physics and Biology. Subjects such as AS Product Design, Computing and Statistics were also studied. Students' details are displayed in Table 6.11 below.

Ethnicity				Entitlement to Free School Meal (FSM)		One or more parent(s)/guardian(s) previously completed a University degree	
White	Black	Asian	Mixed	Yes	No	Yes	No
39%	11%	46%	4%	18%	82%	36%	65%

Table 6.11: Details on students' ethnicity and socio-economic background

Overall, the results show the students represented a varied sample and were from different ethnicity and socio-economic backgrounds. A significant association between parents' degree and entitlement to FSM was also found, and fewer pupils who were entitled to FSM had parents who had degrees (15%) than those who were not (40%) ($p<0.001$, chi-squared test).

Students entitlement to FSM and a parent having a degree or not was further explored between different ethnicity groups using a chi-squared test. The p-values are presented in Table 6.12.

Response: "yes"	White	Black	Asian	Mixed	p-value
Entitlement to Free School Meal (FSM)	6%	33%	21%	32%	<0.001***
One or more parent(s) /guardian(s) previously completed a University degree	43%	37%	28%	53%	0.006**

Table 6.12: The association between students' ethnicity background and entitlement to FSM and parents with a university degree, and; Key: * $p<0.05$; ** $p<0.01$; *** $p<0.001$

The results showed that there is a statistically significant difference in students responses based on their ethnicity and their entitlement to FSM ($p<0.0001$, chi-squared test). Of the White ethnic students, 6% appeared to be entitled to FSM whereas for Black students it was 33%. A statistic difference was also found between ethnicity and whether or not a parent had completed a university degree ($p=0.006$, chi-squared test). Of those, students from an Asian background appeared to have the lowest proportion of students whose parents had a degree (28%) and for White students it was 43%. Thus, a significant association is observed between these variables, suggesting that they are not totally independent of each other.

6.3.1 A Level student participation in STEM outreach activities

35% of the sample had participated in STEM outreach activities. They provided detailed information on their involvement and the impact of the experience and suggested ways of improving their experience. Details about their participation are illustrated below. Some students were involved in several outreach events in different years and different STEM subjects (see Figure 6.15).

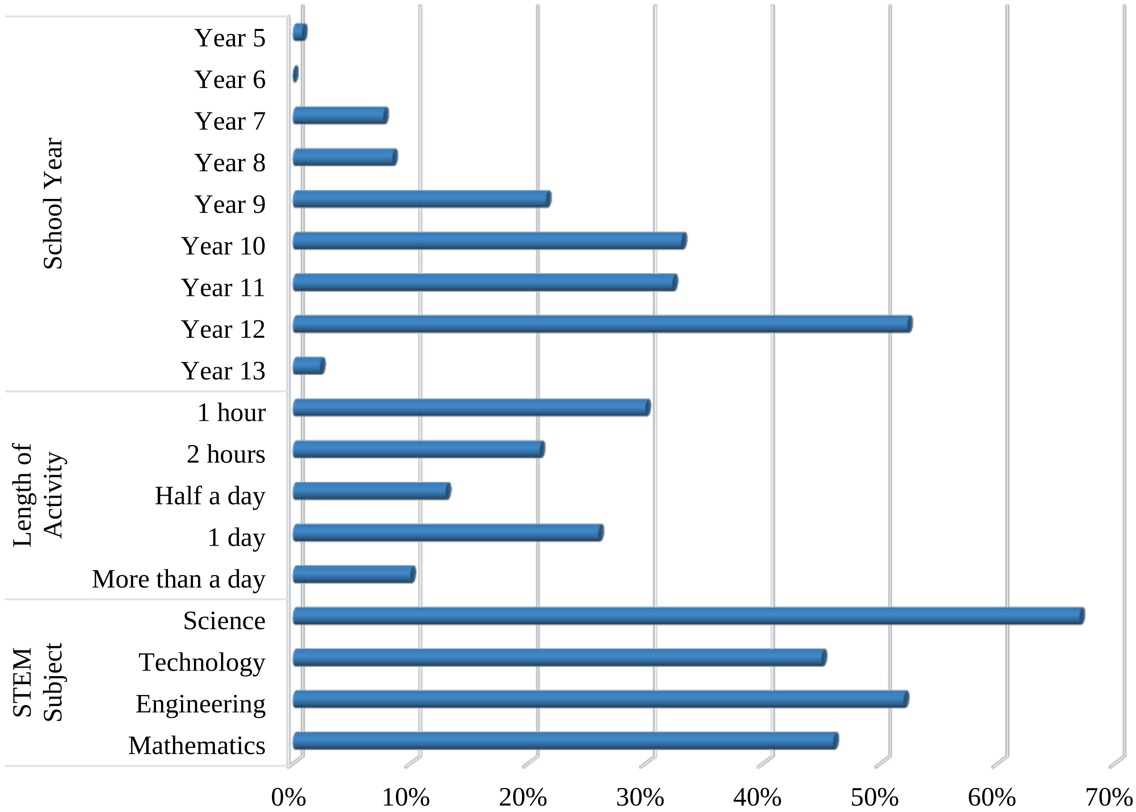

Figure 6.15: Details on student participation in STEM outreach activities

The students' ability to recall their experience for the survey implies that they have retained information on STEM activities that took place up to seven years ago. This involvement overall varied in length. Further, the results show that the majority of outreach activities reported were science related and the second most common area of STEM outreach was engineering.

A range of activities was detailed, including building wind turbines, game designing, making machines/robots and completing a Nuffield research placement. The three types of activities students were mostly engaged in were master classes/lectures (40%), STEM days (38%) and competitions (35%) (see Figure 6.16).

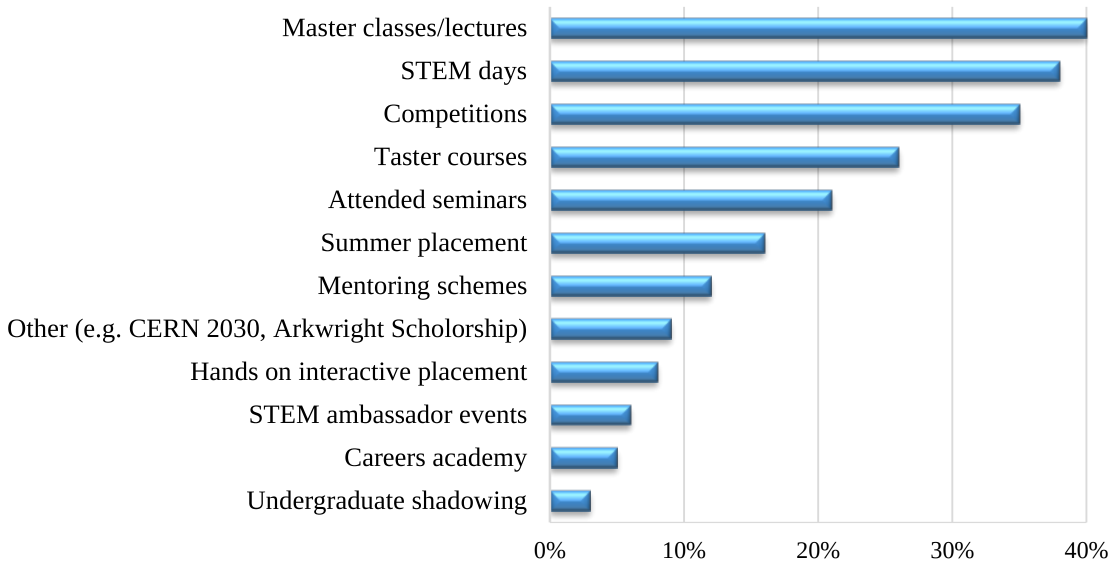

Figure 6.16: Student engagement in a type of STEM outreach activity

Students' recommendations on the areas they thought required addressing for future STEM activities are shown in Figure 6.17.

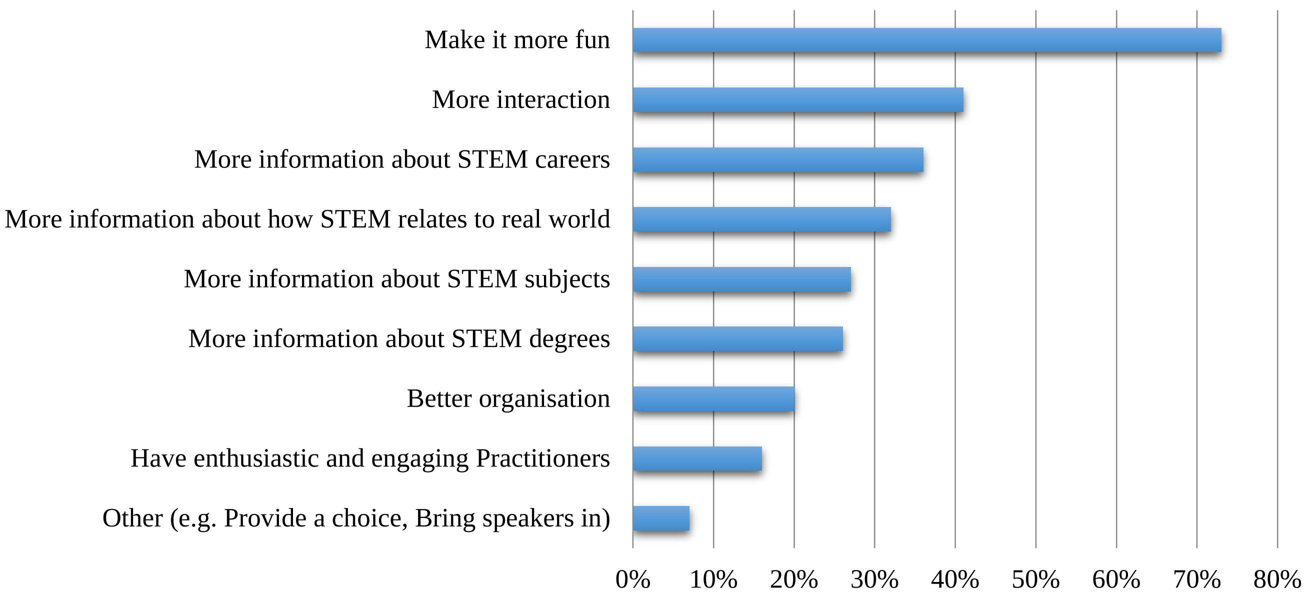

Figure 6.17: Student feedback on improving STEM activities

A level students have shown themselves to be focused on serious outcomes, though *“more fun”* and *“more interaction”* still score very highly indicating that it is not just GCSE students who think this. The A level students proposed improvements related to having more information on careers (36%) and degrees (26%) in the field of STEM, reflecting priorities for this age group. A report by the National Audit Office (2014) highlighted the importance of ensuring students understand the options and are provided with accessible information on careers and degrees (Morse 2014). The research findings on which this report was based indicated that some UK students aged 16-18 receive limited careers advice, confirming findings from Ofsted, which in 2013 found only one in five schools supported their students with essential careers information (Ofsted 2013).

There was a mixed response from the A level student respondents on whether or not they received assistance with understanding their course and career options (this will be discussed in detail later in section 6.3.2). However, the survey responses provide an indication that most students are seeking quality advice and are expecting this to be achieved by participating in STEM outreach activities, if not from their school lessons.

The A level students suggested that a greater element of fun (73%) and interaction (41%) would improve outreach activities. Overall, the feedback from participants signifies key elements that if incorporated effectively can support the enhancement of students’ experiences of STEM outreach activities.

6.3.1.1 Impact of STEM outreach on A level students

The relationship between student participation in STEM outreach activities and their gender, ethnicity and socio-economic background are explored. For each association, through a chi-squared test its p-value is presented outlining significant differences (see Figure 6.18).

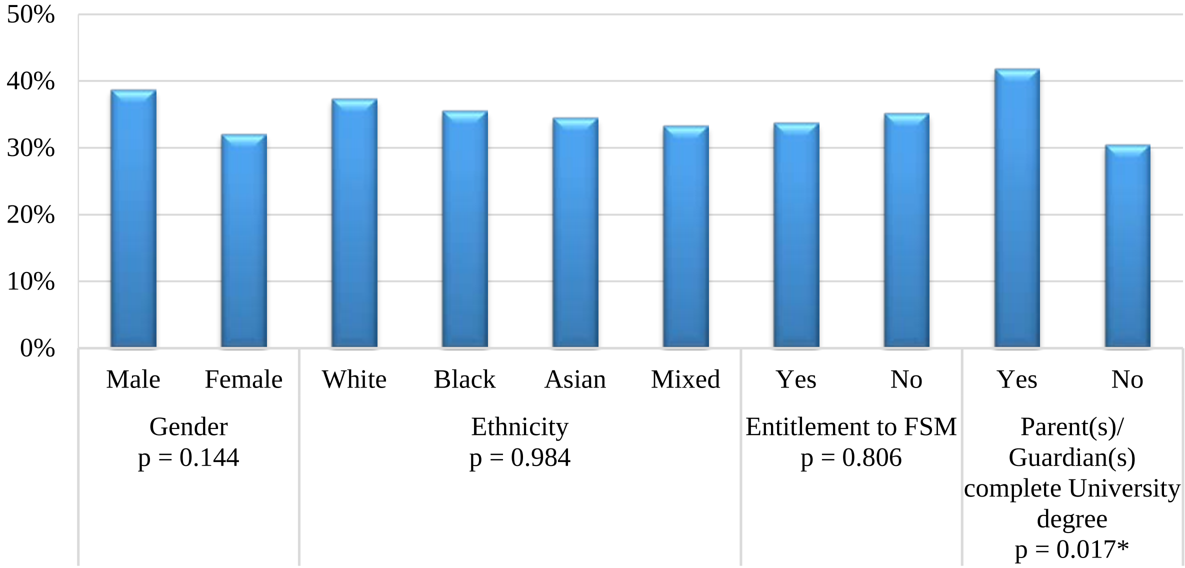

Figure 6.18: Student participation in STEM activities dependent on gender, ethnicity and socio-economic background, and; Key: * p<0.05; ** p<0.01; *** p<0.001

Considering the profiles of students taking part in STEM outreach, no evidence emerged of a statistical difference between participation from females, Black and ethnic minorities and of those entitled to FSM (p>0.05 for all groups, chi-squared tests). Thus, overall, the initial impact of outreach efforts to increase participation of minority groups seems promising and attempts to engage students from different demographic backgrounds can be observed from the survey. However, one factor that appears to significantly influence greater participation is whether parents have completed a university degree (p=0.017, chi-squared test). Therefore, these findings suggest greater focus is needed towards increasing participation from students whose parents are not university graduates.

The responses summarised in Figure 6.19 illustrate students' perceptions about the impact of the STEM outreach activities they experienced.

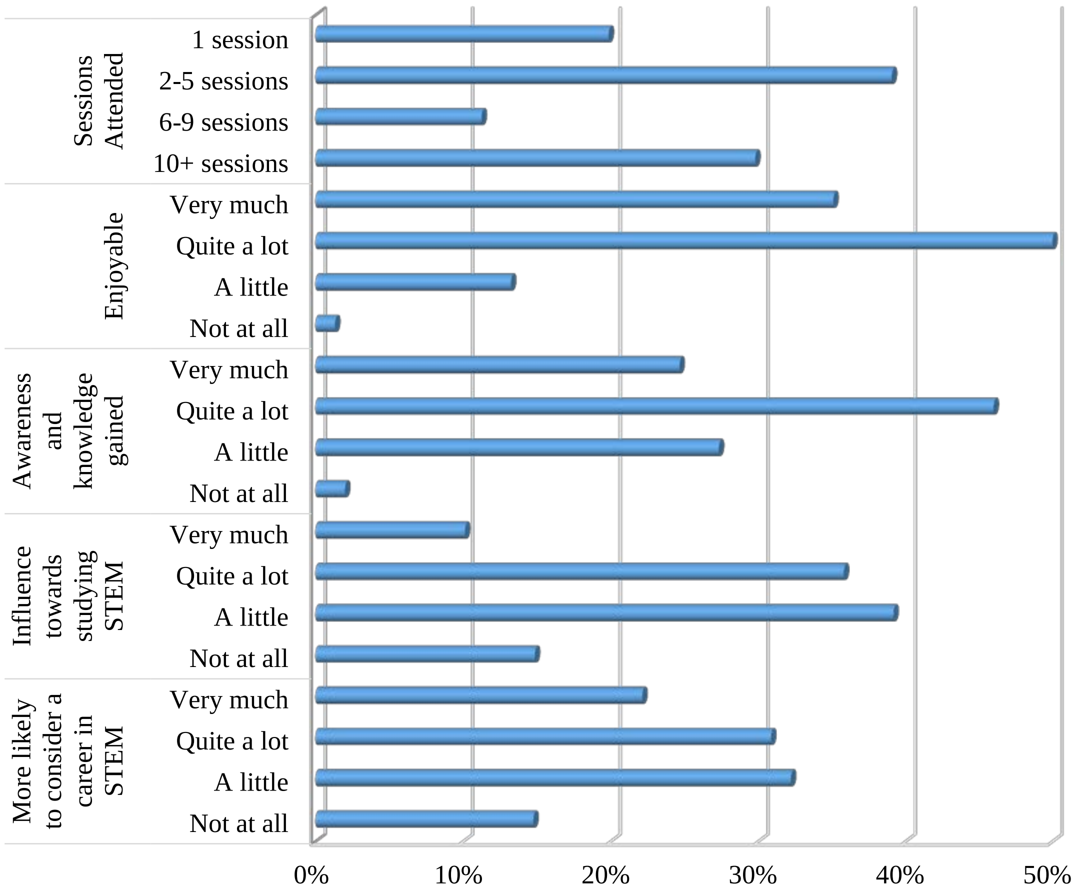

Figure 6.19: Impact of STEM outreach activities

The results show that students have engaged in various numbers of sessions and overall found their experience enjoyable. Also the findings suggest participating in STEM outreach activities has considerably improved students' awareness and knowledge in STEM subjects, and positively made a difference to their likelihood of further studying and pursuing a career in STEM. In order to further understand the findings illustrated in Figure 6.19, the Spearman's rank correlation coefficient has been calculated for each of the above variables (see table 6.14).

Correlations

			Sessions attended	Enjoyment	Awareness and knowledge	Influence towards studying STEM	More likely to consider a career in STEM
Spearman's rho	Sessions attended	Correlation Coefficient	1.000	0.201	0.124	0.149	0.171
		Sig. (2-tailed)	.	0.014*	0.134	0.073	0.040*
		N	151	148	147	145	146
	Enjoyment	Correlation Coefficient		1.000	0.404	0.317	0.395
		Sig. (2-tailed)		.	<0.001***	<0.001***	<0.001***
		N		151	150	148	149
	Awareness and knowledge	Correlation Coefficient			1.000	0.507	0.444*
		Sig. (2-tailed)			.	<0.001***	<0.001***
		N			150	148	149
	Influence towards studying STEM	Correlation Coefficient				1.000	0.602
		Sig. (2-tailed)				.	<0.001***
		N				148	148
	More likely to consider a career in STEM	Correlation Coefficient					1.000
		Sig. (2-tailed)					.
		N					149

Table 6.13: Spearman's rank correlation coefficient, and; Key: * p<0.05; ** p<0.01; *** p<0.001

Table 6.13 highlights the variables that are related to each other. The evidence suggests there is a mild significant relationship between the number of sessions attended and finding the activities enjoyable (p<0.014, Spearman's rank correlation). This describes a reasonable connection as after some time the students are voluntarily able to participate in the activities (e.g. STEM clubs, competition based activities), and so if they have enjoyed and valued their previous experience, the possibility of them engaging in a range of STEM activities are most likely to be high. In addition, evidence shows those students who took part in more sessions were significantly more likely to consider a career in STEM (p=0.040, Spearman's rank correlation). Similar views on the association between a student's level of interaction and career aspiration have been described by other authors (Laursen et al. 2007; Archer 2013), such that to make a long-lasting impact towards the career a student aspires to require several inspirational moments, and not "one-off events". In addition, a significant evidence of a positive correlation was found between students' level of enjoyment and their understanding in, influence towards and aspiration to follow a career in STEM (p<0.001, Spearman's rank correlation).

Possible statistical differences between genders (Mann-Whitney U test) and for different ethnicity groups (Kruskal Wallis test) are also investigated. Using the scoring of each ordinal-scaled question presented in Table 6.4, the median and the mean for each group with the p-value for the former is calculated, where a higher value indicates a greater impact of STEM outreach.

	Gender			Ethnicity				
	Male	Female	p-value	White	Black	Asian	Mixed	p-value
Sessions attended	2.0 (2.3)	2.0 (2.7)	0.035*	2.0 (2.6)	2.0 (2.2)	2.0 (2.6)	1.5 (1.8)	0.281
Enjoyment	3.0 (3.2)	3.0 (3.2)	0.767	3.0 (3.3)	3.0 (3.4)	3.0 (3.1)	3.0 (3.2)	0.226
Awareness and knowledge	3.0 (2.9)	3.0 (2.9)	0.995	3.0 (2.9)	3.0 (3.3)	3.0 (3.0)	3.0 (2.5)	0.094
Influence towards studying STEM	2.0 (2.4)	3.0 (2.5)	0.356	2.0 (2.3)	3.0 (3.1)	2.5 (2.4)	1.5 (1.8)	0.008**
More likely to consider a career in STEM	2.0 (2.5)	3.0 (2.7)	0.260	2.0 (2.5)	4.0 (3.2)	3.0 (2.6)	1.5 (2.0)	0.048*

Table 6.14: The median (mean) of students from different gender and ethnicity based on the details provided on the impact of STEM outreach activities, and; Key: * p<0.05; ** p<0.01; *** p<0.001

The above table displays a statistical significant difference in the number of sessions attended across gender as on average girls indicate to have engaged in more STEM outreach than boys ($p=0.035$, Mann-Whitney U test). Therefore, it seems the girls overall were given more opportunities to engage and experience STEM activities than boys, further reflecting a positive contribution towards the efforts made by outreach.

It was also found that the median was statistically different amongst students from various ethnic groups that expressed being influenced and aspiring to a career in STEM ($p=0.008$ and 0.048 respectively, Kruskal Wallis tests). Overall students from a Black and Asian ethnic background were more inspired towards taking up STEM subjects as well as careers.

6.3.2 Key decisions of A level students

At the A level stage students' decisions are pivotal for their career prospects and, therefore, preparing them with "the tools, skills and knowledge to make an informed decision" is a key incentive (DfE and Gyimah 2015). Students after sixth form completion are able to decide on their next route, whether that be in education, (un)employment or training (National Careers Service 2016).

The options chosen by these students, according to their survey responses, are displayed in Figure 6.20. Some respondents selected more than one option and, therefore, the sum of the percentages is greater than one hundred.

Amongst this group of students, the decision to progress to higher education (83%) after gaining their post-16 qualifications was by far the most popular option. This agrees with the findings of Payne (2003) who highlighted that those who stay in education after age 16 are often driven by the desire to go to university. Thus, the results from this current study are promising as figures published by the Department for Business, Innovation and Skills (2015), estimated that the Higher Education Initial Participation Rate for the 2013/14 academic year was 47% (Ilochi 2015).

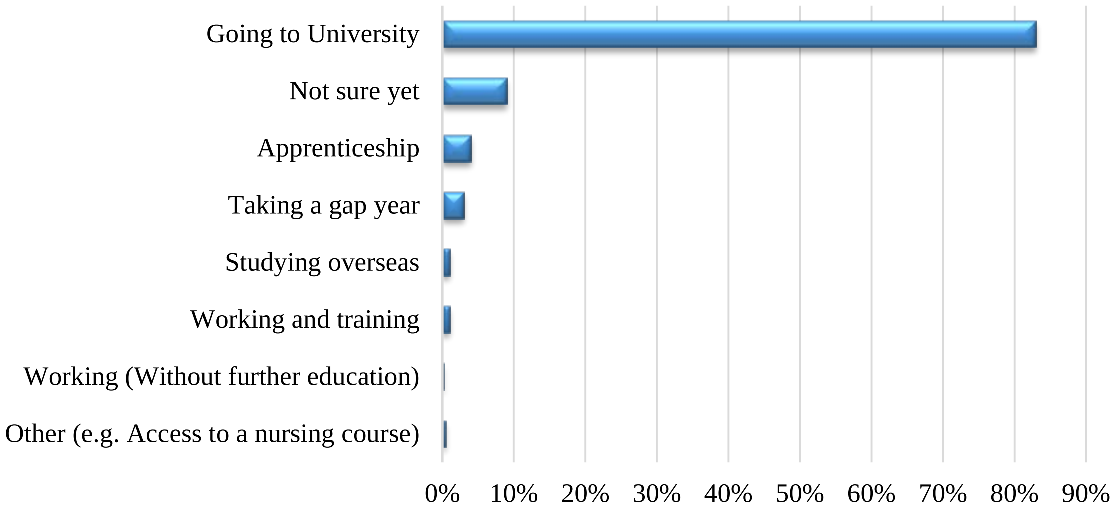

Figure 6.20: Post-18 options considered by A Level students

The Department for Education's recent statutory guidance (2015) outlined strategies in place to support a greater proportion of students continuing in education and training or work. The guidelines set out detail the aim of ensuring schools provide students with an adequate level of advice on career options throughout their time at school to support them with key decision-making. The results from this current survey show that almost a tenth of the A level student respondents (9%) were unsure what option to take, and overall very few respondents appeared interested in taking on a Higher Apprenticeship training scheme (4%) as an alternative to university.

Another area investigated was whether and when advice and guidance were received by the students from their school to support their post-18 decision-making process (see Figure 6.21). Almost two thirds responded with a "yes" and this for the majority of the students occurred during year 11 (47%) or in year 12 (61%).

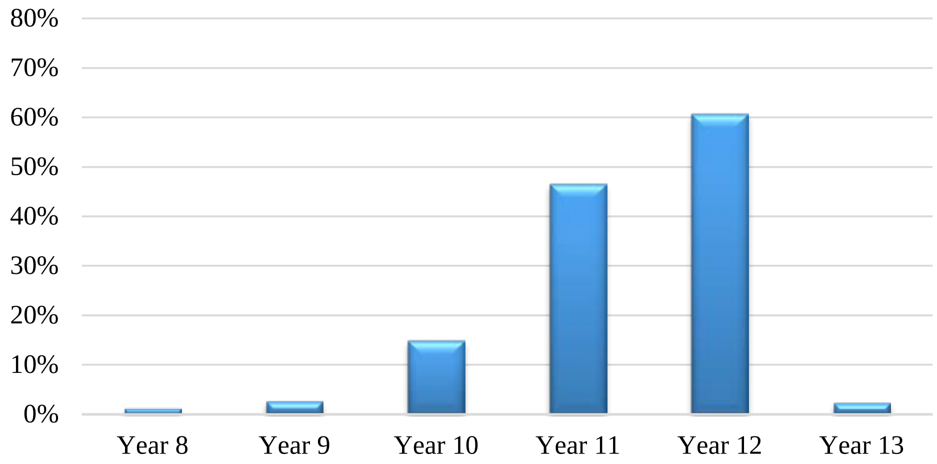

Figure 6.21: School year of when A level students were made aware of the available post-18 options

6.3.3 Key influences of A level students

The students are at a critical stage in their educational journey and their decisions can impact their future job prospects, as well as contribute towards developing the economy (Baum, Ma and Payea 2013). The key factors that have influenced students' post-18 choices are detailed below (see Figure 6.22). In many instances, students chose more than one factor, indicating the complexity of this process and, therefore the overall response as a percentage was greater than one hundred.

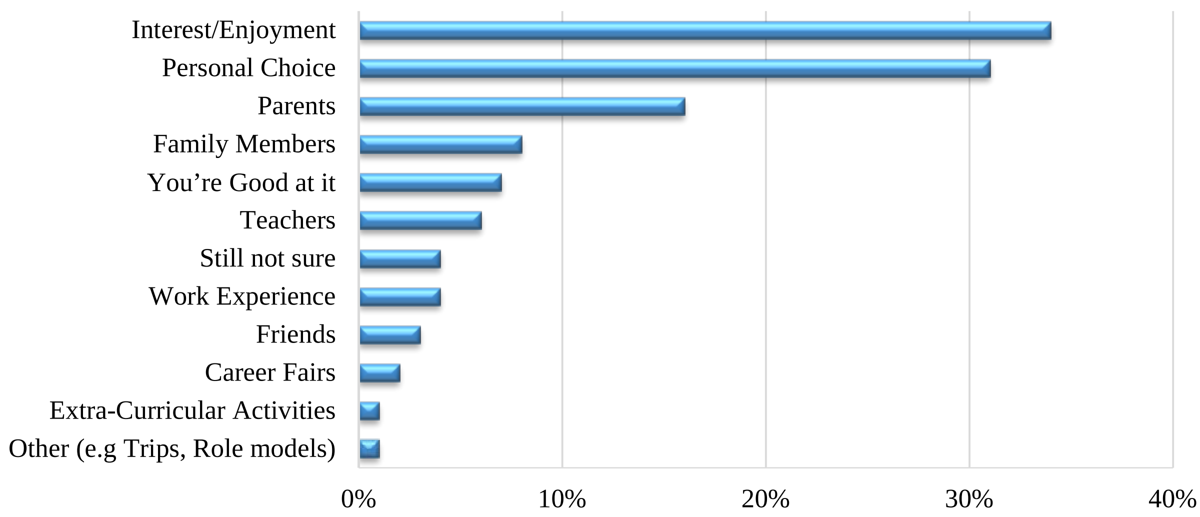

Figure 6.22: Factors influencing A level students towards making key post-18 decisions

A similar proportion of students identified that their level of interest and/or enjoyment as well as personal choice supported this decision. Additionally, the views of their parents and family members contributed towards this decision-making process. Of those variables that were most frequent, the responses provided by students have been analysed according to gender and ethnicity using a chi-squared test (see Table 6.15).

	Gender			Ethnicity				
	Male	Female	p-value	White	Black	Asian	Mixed	p-value
Interest/ Enjoyment	35%	33%	0.700	45%	25%	28%	32%	0.002**
Personal Choice	26%	34%	0.064	21%	31%	39%	32%	0.002**
Parents	16%	16%	0.916	13%	17%	21%	16%	0.236

Table 6.15: The association between factors influencing post-18 decisions with gender and ethnicity, and; Key: * $p<0.05$; ** $p<0.01$; *** $p<0.001$

No evidence of an association was found between gender and a source of influence ($p>0.05$, chi-squared test); although of the females, a slightly greater proportion viewed their personal preference as a key reason to support their post-18 decision than of the males, and this difference was marginally significant ($p=0.064$, chi-squared test). A review by Payne (2003) found “girls go about the process of choosing post-16 routes more efficiently than boys”. Though the age group Payne refers to is slightly younger than the students from this current study, the characteristics she described in a girl may explain why many are more certain towards their decision than boys at a later stage. To support her view, she further shared a finding from Varlaam and Shaw (1984), who stated “girls who planned to stay on in full-time education after 16 were more likely than boys to know exactly how long they would stay and which courses they would take”.

A statistical difference was found between students of different ethnic groups and their responses to two key factors that could influence their post-18 decision. Of the White students, a greater proportion appear to prioritise their interest and enjoyment towards a subject than students from the other ethnic groups ($p=0.002$, chi-squared test). Nevertheless, they significantly expressed the least likelihood of choosing their course based on a personal preference ($p=0.002$, chi-squared test). Whereas for Asian students, personal preference was their key reason towards influencing their decision compared to the responses given by Black and Mixed students. A University of Oxford (2014) commissioned study reported that by year 12, White working class students were at a greater risk of being disengaged from learning than their peers from other ethnic groups (Stamou et al. 2014).

Further research by the University of Plymouth (2013) described the differences found in student attainment in higher education (Cotton, George and Joyner 2013). A key finding from their qualitative data proposed “White students are more likely to be intrinsically motivated (by interest in the subject, personal development etc.) than Black and ethnic minority students”. These findings can propose an insight as to why there are fewer White ethnic students not in education, employment or training (NEET). It seems that interest and enjoyment are key factors that can motivate White students to connect and value the essence of learning. Further research in this area could provide more detailed information about the reasons behind these different responses from different ethnic groups.

6.3.4 Level of understanding of STEM subjects of A level students

A level students’ level of understanding of what certain STEM subjects are, including mathematics, physics, chemistry, biology, engineering and computer science was explored in the survey (see Figure 6.23).

Overall students’ understanding of mathematics was found to be high (69%) and understanding of the three sciences was generally satisfactory. These results are encouraging as qualifications in these subjects are often required by universities for entry to certain STEM courses. Further, irrespective of future career aspirations, familiarity with these subjects keeps students' options open (Tickle 2013; Bates 2014; Gardner 2015).

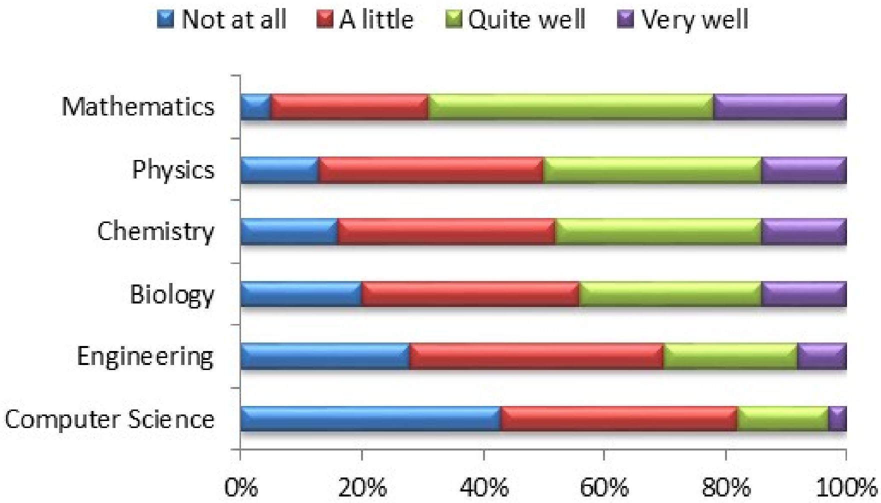

Figure 6.23: Level of understanding of STEM subjects

Although a small number of students initially reported studying engineering and computer science subjects at post-16, overall few students said they understood these subjects well or very well. Responses to this question strongly indicated a low level of understanding for these subjects, as the majority either responded with "not at all" or "a little" (70% (engineering) and 82% (computer science)). Students' limited knowledge and recognition of these two subjects has been highlighted as a concern in many studies (Cox 2015; Kumar, Randerson and Johnson 2015; Zecharia et al. 2014). This evidence explains the reluctance of many students to consider a career or degree in these areas.

Whilst using the questionnaire as a tool to capture key information has been useful, the drawback to self-assessment is that different students may have interpreted the question differently. As the students could be responding to either their general awareness of what the STEM subject is or their ability of using the subject and the theory. Further, a response chosen from the Likert scale (e.g. "a little") may not measure the same level of understanding when the responses is recorded by different students. Thus, although through self-assessment the students are able to provide a meaningful insight, a further discussion and investigation on the students' responses may have provided a more rigorous insight on their understanding for each key STEM subject.

Table 6.16 provides results from analysis of responses about subject knowledge broken down according to gender, ethnicity and whether or not a student had participated in a STEM outreach activity. Using the scoring of each ordinal-scaled question shown in the key of table 6.16, the median and the mean for each group is calculated, together with the p-value for the former, where a higher value indicates a better understanding of what the subject is.

The below table provides a greater understanding of how students perceive their knowledge in certain STEM subjects after taking gender, ethnicity and differences in outreach participation into account. The results show that boys significantly expressed greater confidence towards understanding physics, engineering and computer science subjects than girls ($p<0.001$ for all three subjects, Mann-Whitney U tests). Hence, for those the median (mean) value for boys is greater or equal to the median (mean) value for girls, and it appears on average the girls believed their understanding of computer science in particular was almost non-existent (median=1.0 and mean=1.7). In addition, a mild difference in gender was also found towards understanding mathematics, where again boys perceived a stronger understanding than girls ($p=0.016$, Mann-Whitney U test). Nevertheless, the reverse is shown for the subject biology, as this was significantly better understood by more girls than boys ($p<0.001$, Mann-Whitney U test), and no statistical difference was found towards understanding chemistry as a subject when analysed by gender ($p>0.05$, Mann-Whitney U test). Further, the findings show understanding physics significantly differed across the ethnic groups, and overall was less understood by Black, Asian and Mixed students than White students ($p=0.001$, Kruskal Wallis test).

	Gender			Ethnicity					Participation in STEM outreach		
	Male	Female	p-value	White	Black	Asian	Mixed	p-value	Yes	No	p-value
Mathematics	3.0 (3.0)	3.0 (2.8)	0.016*	3.0 (3.0)	3.0 (2.8)	3.0 (2.8)	3.0 (2.7)	0.266	3.0 (3.1)	3.0 (2.8)	<0.001***
Chemistry	2.0 (2.5)	2.0 (2.4)	0.566	2.0 (2.4)	3.0 (2.5)	3.0 (2.5)	2.0 (2.4)	0.086	3.0 (2.6)	2.0 (2.4)	0.006**
Biology	2.0 (2.2)	3.0 (2.5)	<0.001***	2.0 (2.3)	2.0 (2.4)	2.0 (2.5)	2.0 (2.2)	0.305	2.0 (2.4)	2.0 (2.4)	0.737
Physics	3.0 (2.7)	2.0 (2.4)	<0.001***	3.0 (2.7)	2.0 (2.4)	2.0 (2.4)	2.0 (2.2)	0.001***	3.0 (2.8)	2.0 (2.4)	<0.001***
Engineering	2.0 (2.4)	2.0 (1.9)	<0.001***	2.0 (2.1)	2.0 (2.2)	2.0 (2.0)	2.0 (1.8)	0.662	2.0 (2.5)	2.0 (1.9)	<0.001***
Computer Science	2.0 (1.9)	1.0 (1.7)	<0.001***	2.0 (1.8)	2.0 (1.8)	2.0 (1.8)	1.0 (1.4)	0.262	2.0 (1.8)	2.0 (1.8)	0.676

Table 6.16: The median (mean) of students from different gender, ethnicity and participation in STEM activities, and; Key: 1 = Not at all; 2 = A little; 3 = Quite a bit; 4 = Very much, and; Key: * p<0.05; ** p<0.01; *** p<0.001

Comparing the percentage of girls and boys studying mathematics and science related A level subjects can perhaps help to explain why understanding differed significantly between the boys and girls (see Figure 6.24).

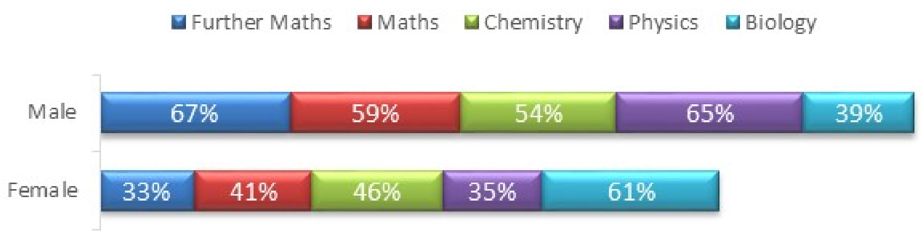

Figure 6.24: The percentage of students studying mathematics and science A level subjects

The above figure displays the gender differences within the cohort of A level student respondents studying STEM related A level subjects. This breakdown is consistent with the current population of 16-19 year old students that study these subjects in the UK. According to the figures published by the Joint Council for Qualifications, in 2015 a considerably greater proportion of boys had entered for A level Further Mathematics (72%), Mathematics (61%), Chemistry (51%) and Physics (79%) than girls (28%, 39%, 49% and 21% respectively), and as found in this current study, the A level entrant numbers showed that Biology was more popular with girls (61%) than boys (39%).

The gender imbalance in STEM subject choices for A level and higher education courses has been recognised as an issue by many reviewers (Roberts 2002; Perkins 2013). The differences in the number of girls studying mathematics and physics have particularly been a cause for concern, and for physics, entrant numbers by girls have stayed low for over 20 years.

Girls' lack of familiarity towards engineering and computer science is a growing concern. Several studies (Holman and Finegold 2010; Institute of Physics 2014; e-skills UK, BCS and The Chartered Institute for IT 2014) have recognised this phenomenon, which also extends to many parents and teachers, who can be key sources of influence for girls.

Nevertheless, the findings of this current research indicate that outreach activities have had some impact towards improving students' self-perception of how well they understand STEM subjects. Those that had participated in STEM activities reported a significantly better understanding of the subjects mathematics, chemistry, physics and engineering than those who had not participated ($p<0.001$, 0.006, <0.001 and <0.001 respectively, Mann-Whitney U tests). On the other hand, students' understanding of computer science and biology was unaffected regardless of whether or not they had taken part in STEM outreach activities ($p>0.05$, Mann-Whitney U test). Thus, overall a positive outlook of STEM outreach is shown, as those that were given the opportunity to engage were predominantly more likely to show a greater connection with and understanding of certain STEM subjects.

6.3.5 Academic stages of understanding STEM careers of A level students

A level students' recognition of available STEM careers is a key way to influence aspirations towards pursuing a career and degree in the area of STEM (Zecharia et al. 2014). Therefore, the questionnaire explored students' self-perception of when they understood the roles of STEM professionals in different specialist areas (see Figure 6.25).

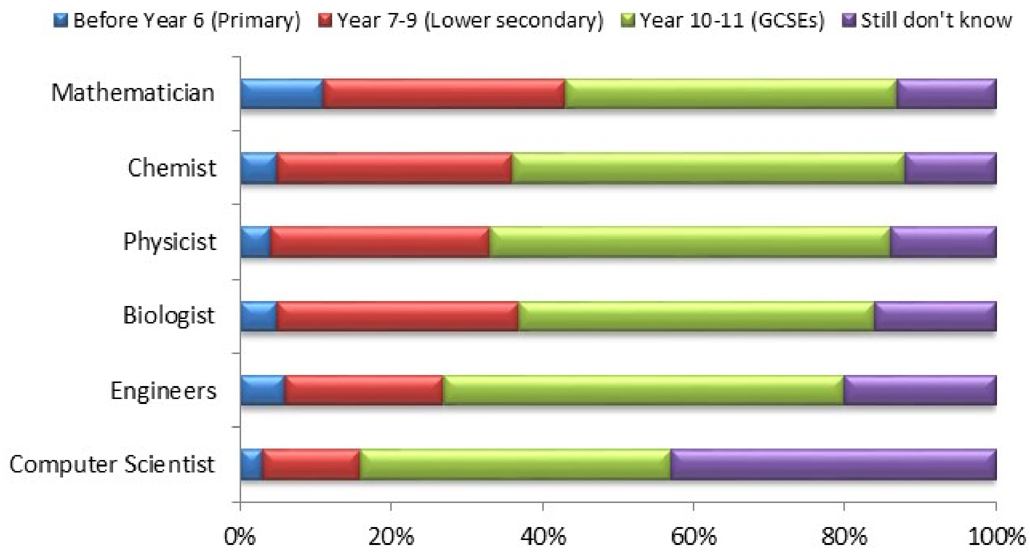

Figure 6.25: Academic stages of understanding STEM careers

Overall, students have shown familiarity with the various types of career roles within STEM, though an exception was found towards the career prospects associated with computer science. They seem to have less understanding of the subject as well as careers (43%). The lack of clarity shown by students is of concern; because if an A level student is not aware of the possible career opportunities, they are highly unlikely to consider this subject area as a future career route. Holman and Finegold (2010) indicate that often career aspirations are already formed by the age of 16-19. They report that although students make their first informal decision on their future career path by the age of 14, some children begin to build an aspiration of a career they would like to follow when they are older during primary education. Thus, receiving quality guidance and forming a general awareness is critical for students of all ages to ensure informed subject and career decisions are adequately made.

The responses to the questions about students' academic stage of awareness on careers have been analysed by gender, ethnicity and whether or not a student participated in a STEM outreach activity. Figures 6.26, 6.27 and 6.28 outline the responses for each profession. Significant difference with independent variables have been noted by a key (* p<0.05, ** p<0.01, *** p<0.001).

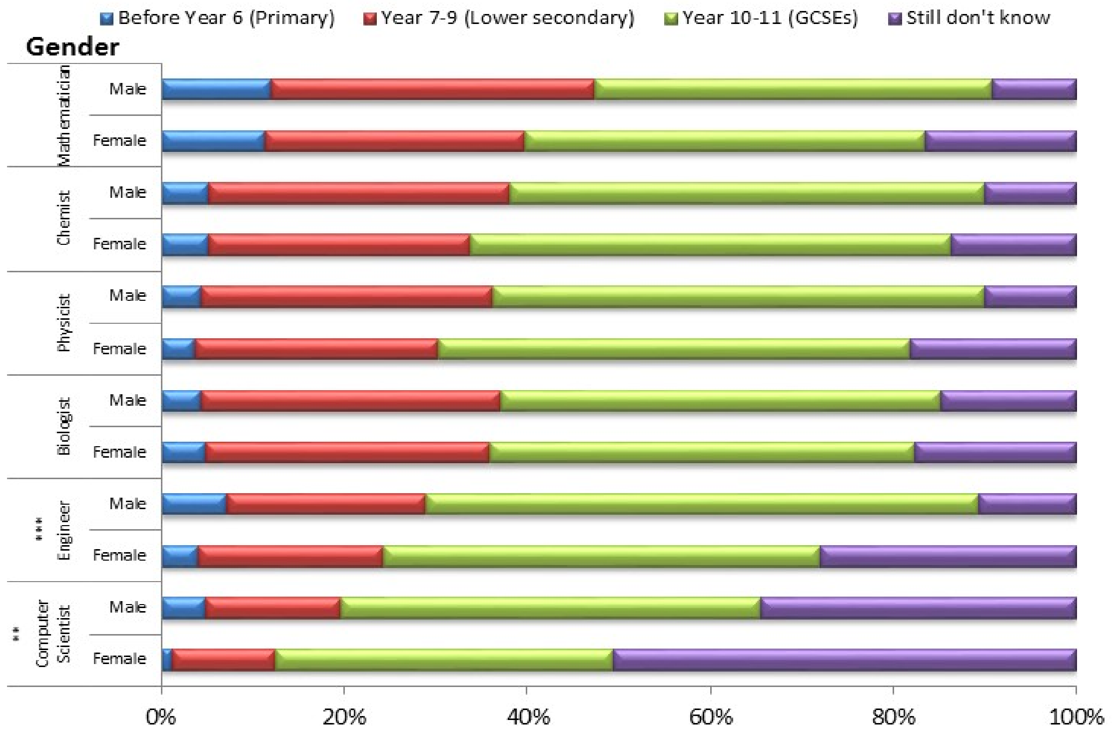

Figure 6.26: The association between students' academic stage of career awareness with gender

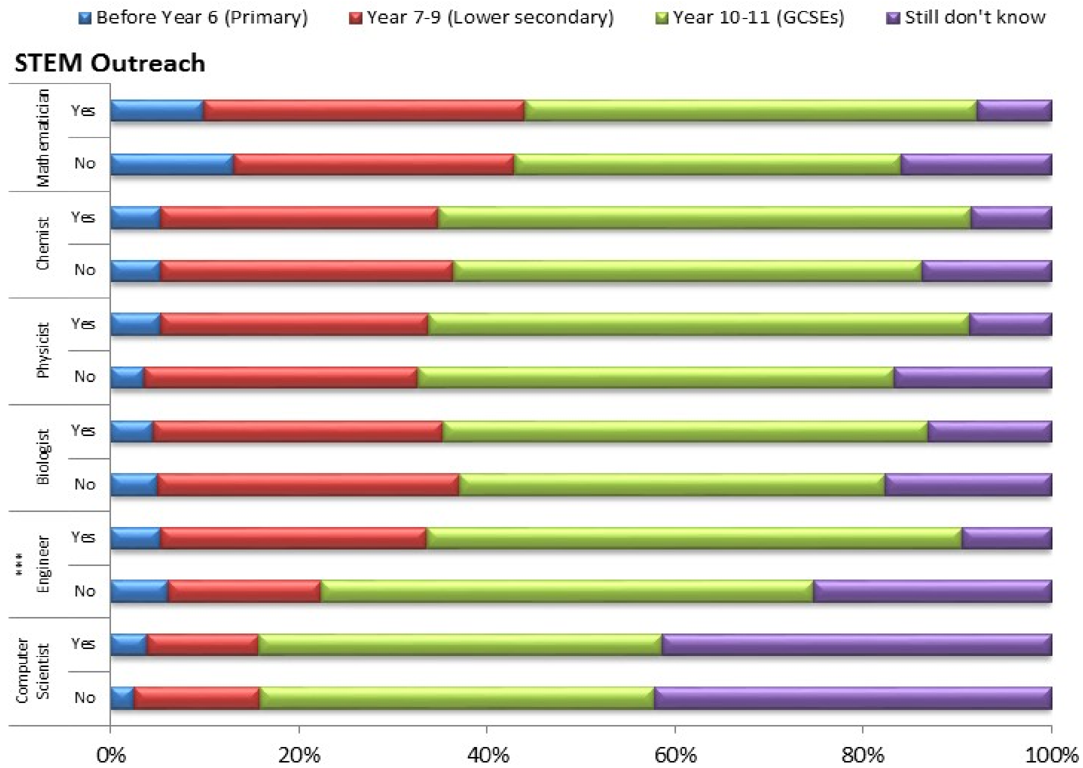

Figure 6.27: The association between students' academic stage of career awareness with participation in STEM outreach activities

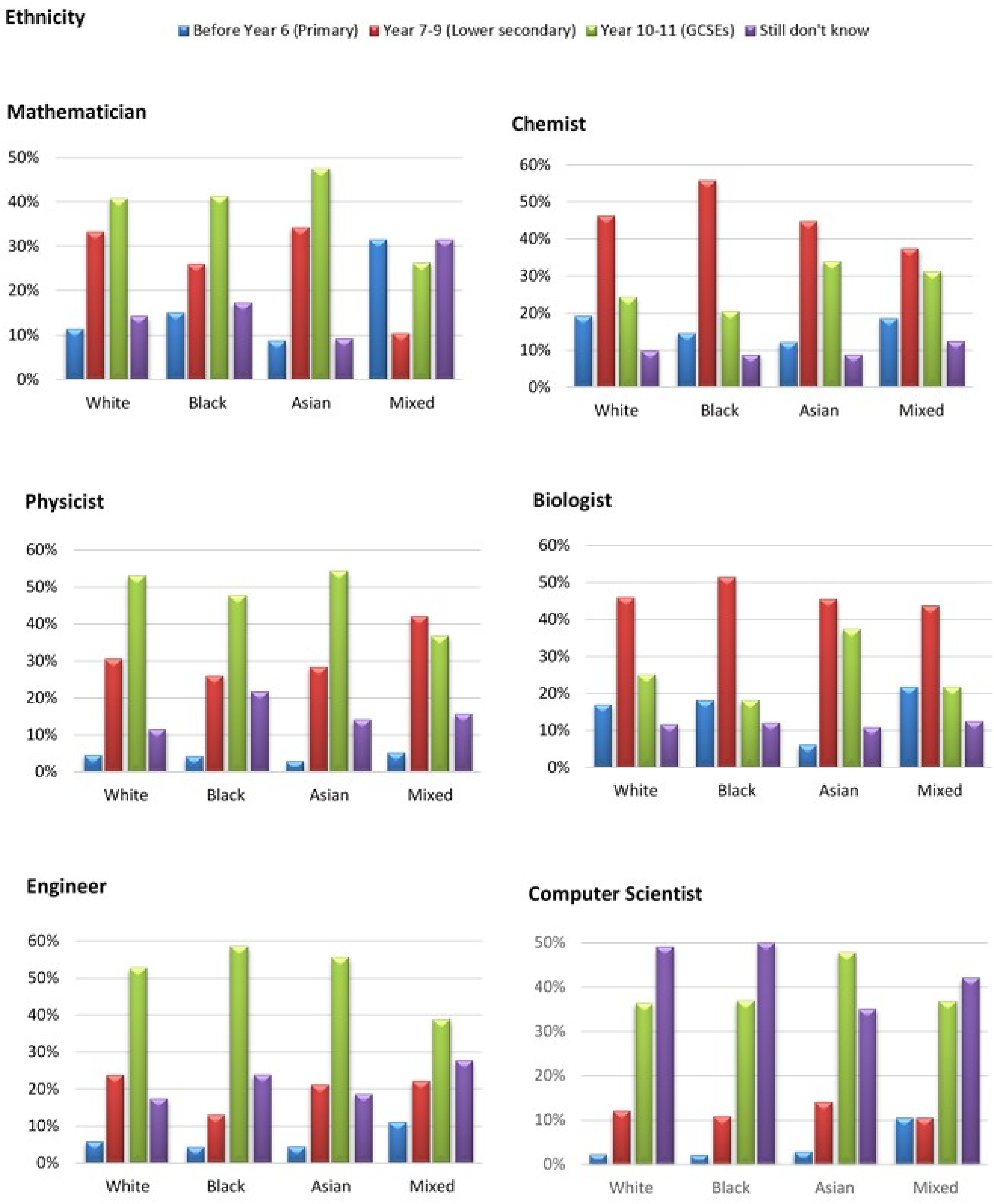

Figure 6.28: The association between students' academic stage of career awareness with ethnicity

The results summarised in Table 6.17, display the p-values calculated from a chi-squared test and Fisher's exact test based on the association between students' academic stage of understanding STEM careers and the variables: gender, ethnicity and students engagement with STEM outreach.

	Mathematician	Chemist	Physicist	Biologist	Engineer	Computer Scientist
Gender	0.091	0.575	0.086	0.850	<0.001***	0.002**
Ethnicity	0.117	0.411	0.723	0.365	0.718	0.163
STEM outreach	0.059	0.362	0.101	0.521	<0.001***	0.815

Table 6.17: Statistical association investigated for each STEM career with gender, ethnicity and STEM outreach participation, and; Key: * $p<0.05$; ** $p<0.01$; *** $p<0.001$

The results indicate that males on average expressed greater awareness towards understanding each of the STEM professions than females. Evidence of a statistical association was found between the academic stages of understanding what engineers and computer scientists do and gender ($p<0.001$ and 0.002 respectively, chi-squared tests). The lack of awareness that women have shown in this study about engineering and computer science related careers has been confirmed through other studies (Mellors-Bourne, Connor and Jackson 2011; House of Lords Select Committee on Digital Skills 2015).

Despite girls on average out-performing boys during their educational journey, this is "not always reflected in their subsequent career aspirations or financial rewards" (Women's Business Council 2013). A study by WISE (2015a) reported the growth from 2014 to 2015 in the number of women employed in STEM occupations. They found the percentage rise in women working in engineering and as ICT professionals were 45%

and 35% respectively, resulting in women making up 14.4% of the UK STEM workforce.

As well as e-skills UK, BCS and The Chartered Institute for IT (2014) providing an insight into the lack of women that are in the IT profession (of the 753,000 people working in the IT sector, 20% were women in 2013), they further described the gender inequality that exists, which starting from school continues through A level, higher education and into the workforce. Adecco (2015), who surveyed almost 3,000 girls, university women and those working in STEM, reported “girls are interested in STEM, but the UK is still only using half of the nation’s brains”. They further found females lacked awareness of how to enter a STEM profession and for that reason, 19% of females did not pursue a career in STEM. The results from this current study correlate with the findings from other studies outlined above and the lack of understanding women have shown towards engineering and computer science related careers reinforces their underrepresentation particularly in this area of STEM.

Evidence was found suggesting that participating in STEM outreach positively influenced students’ responses to the question about knowledge of STEM professions; although many respondents expressed uncertainty about what a computer scientist does. However, when tested for significant differences, a very strong significant association was found between students’ awareness of what an engineer does and whether or not they had participated in STEM activities ($p<0.001$, chi-squared test). This result suggests that outreach may have played a role towards the understanding of several students involved in this study. Participation in outreach activities appears to have contributed significantly towards improving students’ awareness and enriched their understanding of the wide range of roles that exist in the field of engineering, placing them in a better position to help make an informed post-18 decision.

6.4 STEM undergraduate student sample

A total of 1280 first year STEM undergraduate students participated in this study and completed the questionnaire (see Appendix F). The data were collected over time during induction week from three different cohorts; 2012/2013, 2013/2014 and 2014/2015, and from two different universities. Those that participated were studying engineering (965 students), mathematics (140 students) and computing (175 students) related degrees.

Of the sample, 84% were males and 16% were females, and the majority were home students (78%) and had studied A levels (64%) prior to starting their STEM undergraduate course. The remaining proportion of students had studied other types of qualifications including BTEC, a National Diploma and a Foundation degree. Table 6.18 provides further details on students' ethnic background.

Ethnicity				
White	Black	Asian	Mixed	Other
56%	13%	24%	3%	4%

Table 6.18: Details on students' ethnic background

Despite only one in six (16%) of the sample being female, overall the results show the students were from a varied ethnic and educational background.

6.4.1 STEM undergraduate student participation in STEM outreach activities

29% of the sample reported that they had participated in STEM outreach activities, and provided further key information on their involvement and outreach experience. Some students participated in multiple outreach events occurring in different years and in a range of STEM subjects (see Figure 6.29).

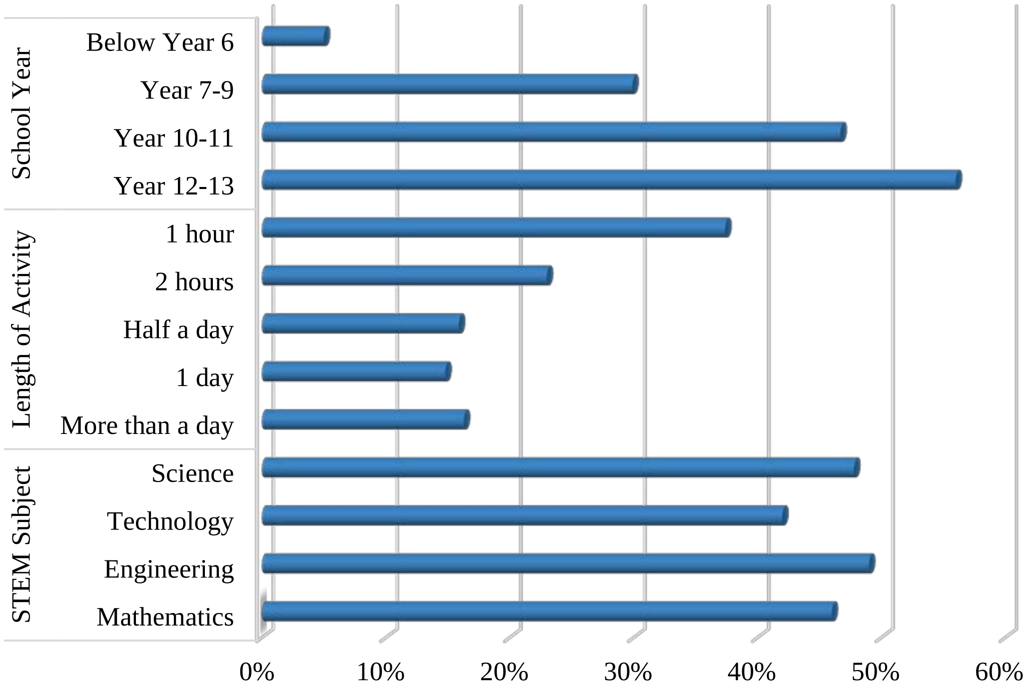

Figure 6.29: Details on student participation in STEM outreach activities

The results show that students had participated in STEM outreach events at different educational stages. Of the sample, similar proportion of students participated in science, technology, engineering and mathematics-related activities.

A range of activities were detailed, including programming, JLR (Jaguar Land Rover) young apprenticeship scheme, and coding and working with robots and machines. Figure 6.30 shows the type of STEM outreach activities the students engaged with.

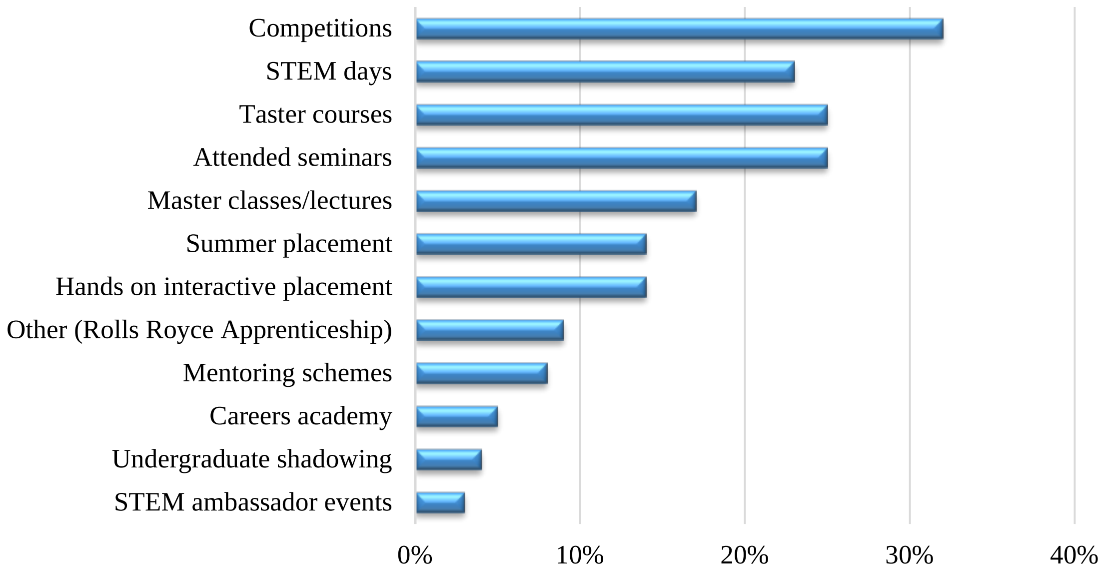

Figure 6.30: Student engagement in a type of STEM outreach activity

Students also provided recommendations on the areas they thought required addressing for future outreach improvement (see Figure 6.31).

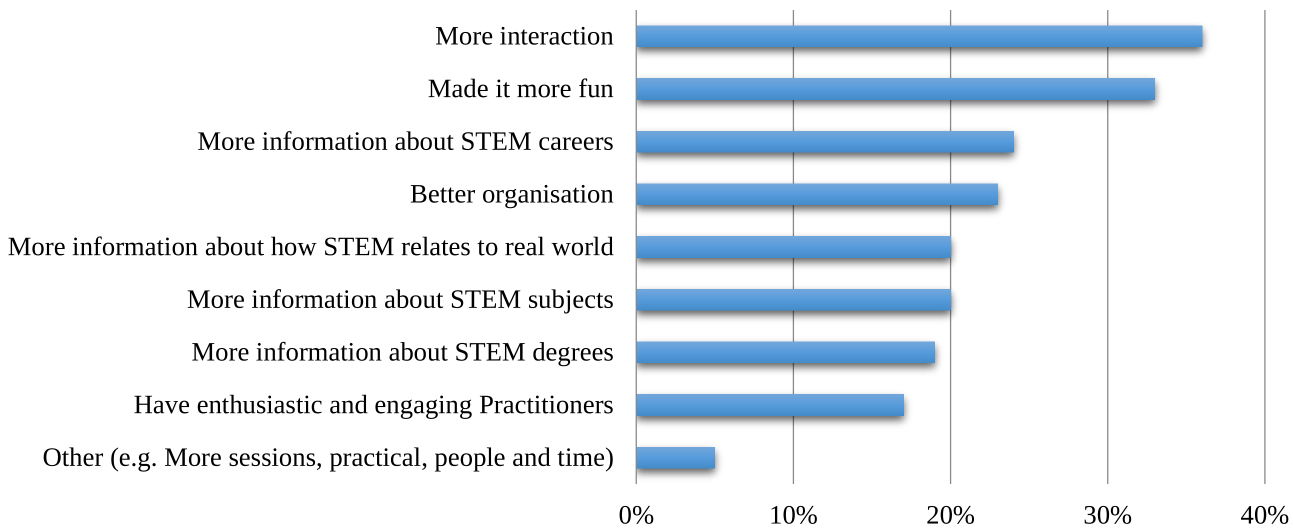

Figure 6.31: Student feedback on improving STEM activities

The results show that the STEM undergraduate students identified a range of approaches that they considered supporting their STEM outreach experience. The four types of suggestions students mostly provided were greater interaction (36%), enjoyment (33%), careers information (24%) and better organisation (23%).

6.4.1.1 Impact of STEM Outreach on STEM undergraduate students

The relationship between student participation in STEM outreach activities and their gender and ethnicity has been explored. For each association, its statistical value is presented outlining significant differences through a chi-squared test (see Figure 6.32).

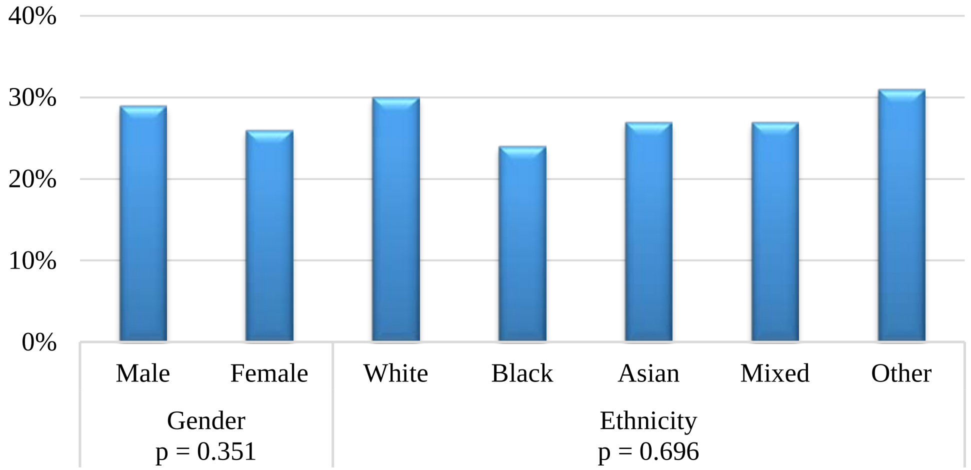

Figure 6.32: Student participation in STEM activities dependent on gender and ethnicity, and; Key: * $p<0.05$; ** $p<0.01$; *** $p<0.001$

Despite there being fewer females and Black and ethnic minorities who interacted with outreach activities than their peers, when tested for significant differences, no statistically significant evidence of an association between gender and ethnicity and the proportion of those that took part in STEM outreach activities was found ($p>0.05$, chi-squared tests). Thus, the results indicate a similar proportion of STEM undergraduate students from different gender and ethnic backgrounds engaged with STEM outreach activities before starting university.

In order to capture a better understanding of the impact of STEM outreach activities, further details on students' involvement and experience are illustrated below (see Figure 6.33).

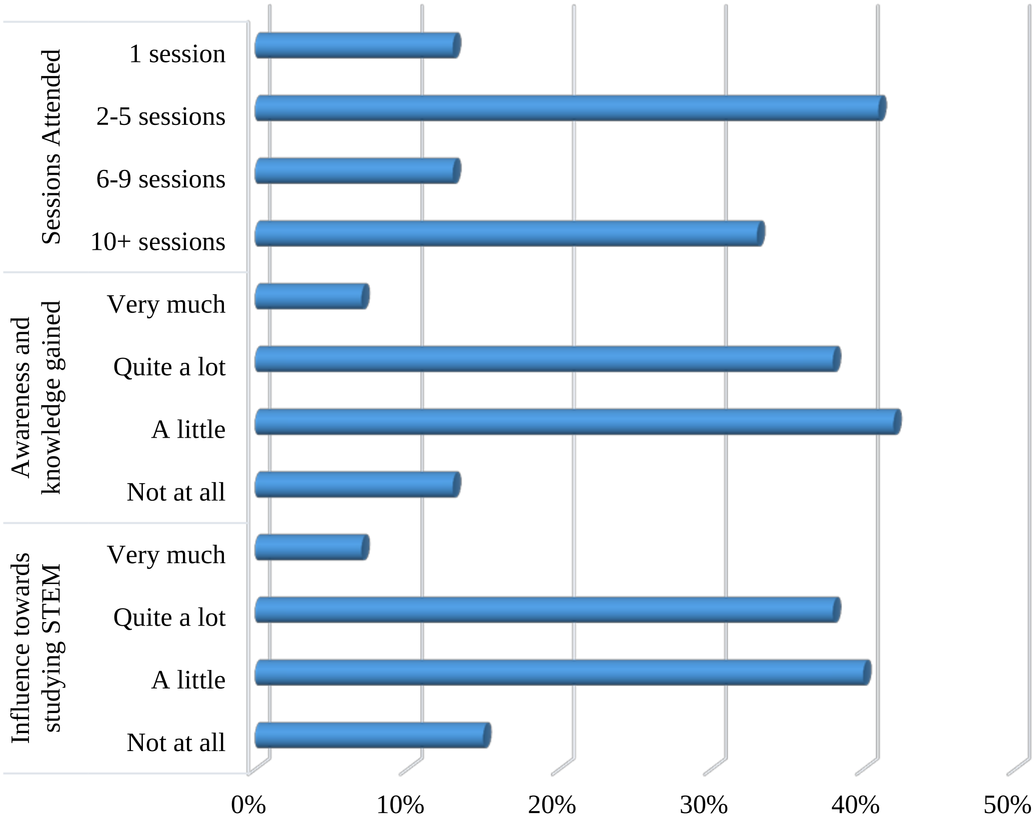

Figure 6.33: Impact of STEM outreach activities

The findings show that typically the students attended a number of sessions and overall found their experience of STEM outreach reasonably interesting. It also shows that the majority of the students considered participation in STEM outreach improved their awareness and knowledge in STEM subjects and contributed towards their decision of studying a STEM undergraduate course at university. In order to further understand the findings illustrated in Figure 6.33, the Spearman's rank correlation coefficient has been calculated for each of the above variables (see Table 6.19).

			Sessions attended	Awareness and knowledge	Influence towards studying a STEM course
Spearman's rho	Sessions attended	Correlation Coefficient	1.000	0.090	0.159
		Sig. (2-tailed)	.	0.161	0.013*
		N	292	245	245
	Awareness and knowledge	Correlation Coefficient		1.000	0.294
		Sig. (2-tailed)		.	<0.001***
		N		295	294
	Influence towards studying a STEM course	Correlation Coefficient			1.000
		Sig. (2-tailed)			.
		N			294

Table 6.19: Spearman's rank correlation coefficient, and; Key: * p<0.05; ** p<0.01; *** p<0.001

Table 6.19 details the variables that are significantly correlated with each other. It suggests there is a positive relationship between students' awareness and knowledge and their likelihood to study a STEM undergraduate course (p<0.001, Spearman's rank correlation). Similarly, the number of sessions attended positively correlated with influencing students' course decisions, and it indicated the greater their engagement in STEM outreach events, the higher the likelihood was for choosing their STEM undergraduate course (p=0.013, Spearman's rank correlation).

Table 6.20 below explores statistical differences between the groups' gender (Mann-Whitney U test) and ethnicity (Kruskal Wallis test). Using the scoring of each ordinal-scaled question presented in Table 6.4, the median and the mean for each group with the p-value for the former is calculated, where a higher value indicates a greater impact of STEM outreach.

	Gender			Ethnicity					
	Male	Female	p-value	White	Black	Asian	Mixed	Other	p-value
Sessions attended	2.0 (2.7)	2.0 (2.5)	0.202	2.0 (2.6)	2.0 (2.6)	2.0 (2.5)	2.0 (2.6)	4.0 (3.2)	0.725
Awareness and knowledge	2.0 (2.4)	2.0 (2.2)	0.109	2.0 (2.2)	2.0 (2.4)	3.0 (2.6)	2.0 (2.5)	3.0 (2.4)	0.093
Influence towards studying STEM	2.0 (2.4)	2.0 (2.2)	0.292	2.0 (2.3)	2.0 (2.3)	2.0 (2.3)	2.0 (2.3)	3.0 (2.7)	0.765

Table 6.20: The median (mean) of students from different gender and ethnicity based on the details provided on the impact of STEM outreach activities, and; Key: * $p<0.05$; ** $p<0.01$; *** $p<0.001$

The results indicate, on average, students from different genders and ethnicities were involved in a similar number of sessions and overall. However, the boys saw themselves benefitting slightly more from their outreach experience than girls (the median and mean values for males are greater than females).

Nevertheless, no statistical difference was found between the details the students from different genders and ethnicities provided with their level of engagement and impact of STEM outreach ($p>0.05$ for gender and ethnicity respectively, Mann-Whitney U tests and Kruskal Wallis tests). This shows students from a range of backgrounds have benefited from taking part in STEM outreach activities. Since these are all STEM undergraduates, the lack of difference between the genders and ethnicity is not surprising.

6.4.2 Key influences of STEM undergraduate students

The key reasons for the selection of a university course in an area of STEM were explored. Some students' selected more than one option and, therefore, the overall responses as a percentage were greater than one hundred (see Figure 6.34).

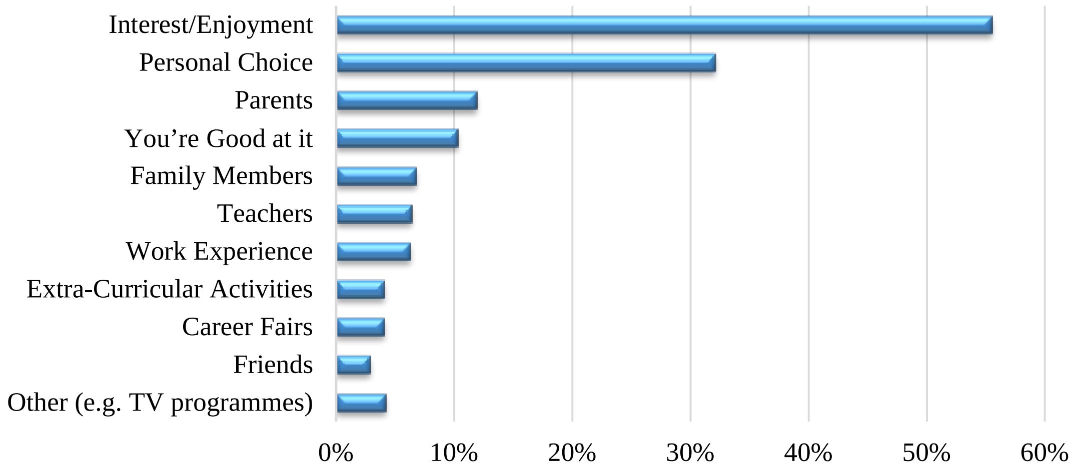

Figure 6.34: Factors influencing STEM undergraduate students towards their university course

A large proportion of students reported their level of interest and/or enjoyment was a key reason that supported their decision of becoming an undergraduate student in an area of STEM. A study by National Union of Students (2011) found similar views as their findings suggested the main reason a course was suitable and chosen by a student in higher education was that their interest reinforced it. Another popular reason outlined from this study was personal preference and for some, there was a parental influence. Of those variables that were most frequently reported, the responses provided by different genders and ethnicity groups have been explored, and for each source of influence, the p-value is calculated from a chi-squared test (X^2) and Fisher's exact test (FE) (see Table 6.21).

	Gender			Ethnicity						
	Male	Female	p-value	White	Black	Asian	Mixed	Other	p-value	Test
Interest/ Enjoyment	57%	50%	0.087	62%	50%	54%	61%	44%	0.016*	X^2
Personal Choice	31%	40%	0.090	27%	34%	29%	36%	31%	0.716	X^2
Parents	13%	8%	0.053	8%	14%	15%	18%	14%	0.011*	FE
You’re Good at it	10%	11%	0.702	11%	15%	8%	7%	12%	0.536	X^2
Family Members	6%	10%	0.028*	5%	10%	6%	11%	17%	0.025*	FE
Teachers	5%	12%	0.001***	6%	10%	10%	4%	3%	0.085	X^2

Table 6.21: The association between factors influencing STEM undergraduate students’ course decisions with gender and ethnicity, and; Key: * $p<0.05$; ** $p<0.01$; *** $p<0.001$

The results indicate teachers were significantly viewed as a stronger influence on the females than they were on the males when making STEM undergraduate course decisions (p=0.001, chi-square test). This was similar for those who chose family members as their key source of influence, as there was significant evidence to suggest when making course decisions, females considered them as a greater influence than males (p=0.028, chi-square test). However, in both cases they influence only a small percentage of females. Interestingly parents are marginally more influential on boys. The other sources of influence showed no significant association to suggest differences by gender occurred within this sample of STEM undergraduate students when making course decisions (p>0.05, chi-square test). Nevertheless, it appears a key reason for White and Mixed students choosing their course was the level of interest and enjoyment they had towards the subject compared to their peers (p=0.016, chi-square test). When tested for statistical differences, it was found that they were significantly less likely to choose their course because of parental and family influence, especially in comparison to students from a Black and Asian background (p=0.011 and 0.025 respectively, Fisher's exact tests). Thus, the Black and Asian students were more likely to view their parents and family members as a key source of influence, supporting their decision-making process of choosing their STEM undergraduate course than their peers.

6.4.3 Level of understanding of STEM subjects of STEM undergraduate students

STEM undergraduate students were questioned on their level of understanding of the subject, which included mathematics, physics, engineering, chemistry and computer science (see Figure 6.35).

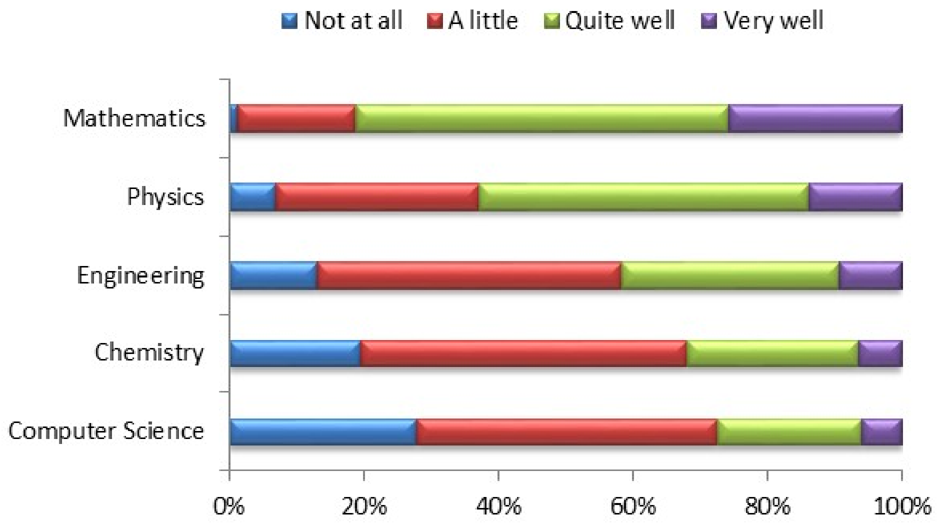

Figure 6.35: Level of understanding of STEM subjects

Overall, the majority of the students expressed a high level of understanding, which is not surprising as the vast majority of the students surveyed were engineering students. However, 25% of undergraduates have reported to have no idea what computer science is.

Table 6.22 displays the survey sample difference in gender, ethnicity, and whether or not a student had participated in a STEM outreach activity towards their understanding of what STEM subjects entail. Using the scoring of each ordinal-scaled question shown in the key below this table, the median and the mean for each group with the p-value for the former calculated, where a higher value indicates a better understanding of the subject.

	Gender			Ethnicity						Participation in STEM Outreach		
	Male	Female	p-value	White	Black	Asian	Mixed	Other	p-value	Yes	No	p-value
Mathematics	3.0 (3.1)	3.0 (3.1)	0.772	3.0 (3.1)	3.0 (3.1)	3.0 (3.1)	3.0 (3.2)	3.0 (2.9)	0.550	3.0 (3.0)	3.0 (3.1)	0.545
Physics	3.0 (2.8)	2.0 (2.4)	<0.001***	3.0 (2.8)	2.0 (2.5)	3.0 (2.6)	3.0 (3.0)	2.0 (2.3)	<0.001***	3.0 (2.8)	3.0 (2.7)	0.196
Engineering	2.0 (2.5)	2.0 (1.9)	<0.001***	2.0 (2.4)	2.0 (2.2)	2.0 (2.3)	2.0 (2.4)	2.0 (2.6)	0.122	3.0 (2.6)	2.0 (2.3)	<0.001***
Chemistry	2.0 (2.2)	2.0 (2.2)	0.888	2.0 (2.1)	2.0 (2.2)	2.0 (2.2)	2.0 (2.3)	2.0 (1.9)	0.429	2.0 (2.2)	2.0 (2.2)	0.557
Computer Science	2.0 (2.1)	2.0 (1.9)	0.001***	2.0 (2.0)	2.0 (1.9)	2.0 (2.0)	2.0 (2.1)	2.0 (2.0)	0.670	2.0 (2.1)	2.0 (2.0)	0.033*

Table 6.22: The median (mean) of students from different gender, ethnicity and participation in STEM activities, and; Key: 1 = Not at all; 2 = A little; 3 = Quite a bit; 4 = Very much, and; Key: * p<0.05; ** p<0.01; *** p<0.001

The results show on average the males expressed a significantly greater understanding of the subjects; physics, engineering, and computer science subjects are than females ($p<0.001$, <0.001 and 0.001 respectively, Mann-Whitney U tests). Further, the findings suggest understanding physics significantly differed across the ethnic groups, and overall was better understood by White students than Black, Asian, Mixed and Other students ($p<0.001$, Kruskal Wallis test). The impact of STEM outreach is also shown, as those that took part in STEM outreach activities overall indicated a better understanding of what the subjects entail than those that had not, and this was statistically significant for the subjects engineering and computer science ($p<0.001$ and 0.033 respectively, Mann-Whitney U tests).

6.4.4 Academic stages of understanding STEM careers of STEM undergraduate students

This study aimed to investigate the differences in students' perceptions of when they understood what different STEM professionals do. The findings are illustrated in Figure 6.36.

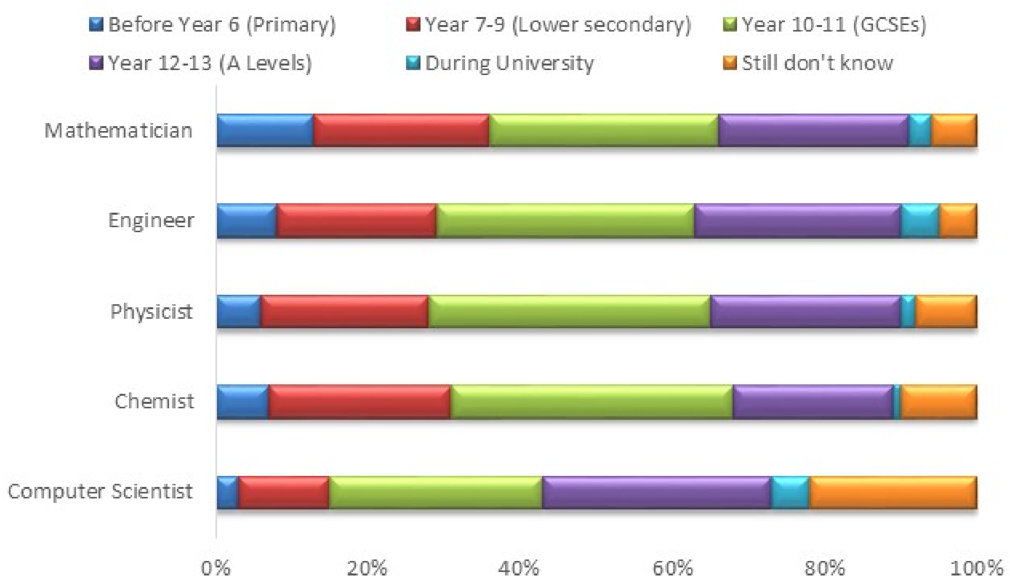

Figure 6.36: Academic stages of understanding STEM careers

An overall majority of the undergraduate students indicated they had developed an awareness of the various types of STEM careers during their academic progression. However, 22% of students appeared unsure on career opportunities that related to computer science, supporting the finding from a study by the Royal Society (2012). They indicated there is a lack of recognition by students on what a computer scientist does and how it can contribute to the economy.

The statistical differences when analysed on gender, ethnicity and whether or not a student participated in a STEM outreach activity with a students' academic stage of awareness on careers was further explored. Figures 6.37, 6.38 and 6.39 outlines these differences. For each profession where significant differences were found, the independent variables have been noted by the use of a key (* $p<0.05$, ** $p<0.01$, *** $p<0.001$).

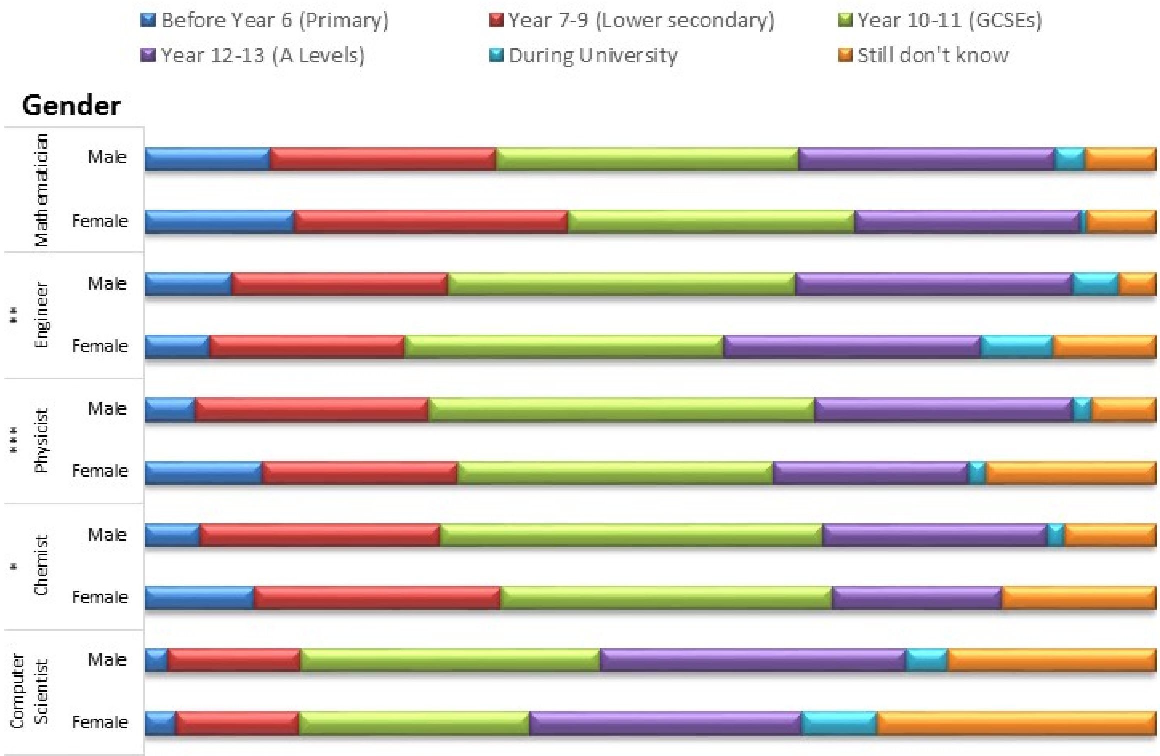

Figure 6.37: The association between students' academic stage of career awareness with gender

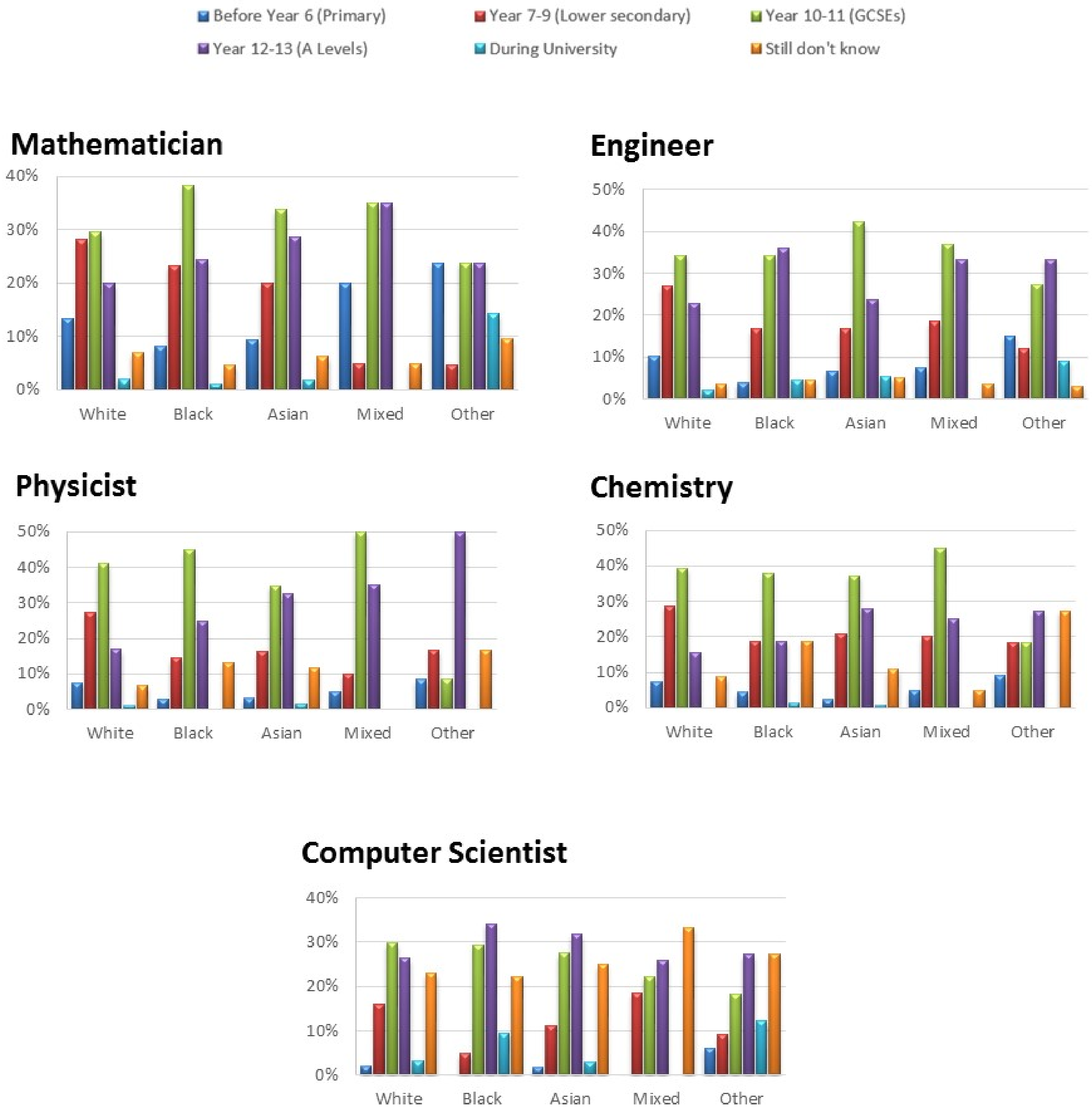

Figure 6.38: The association between students' academic stage of career awareness with ethnicity

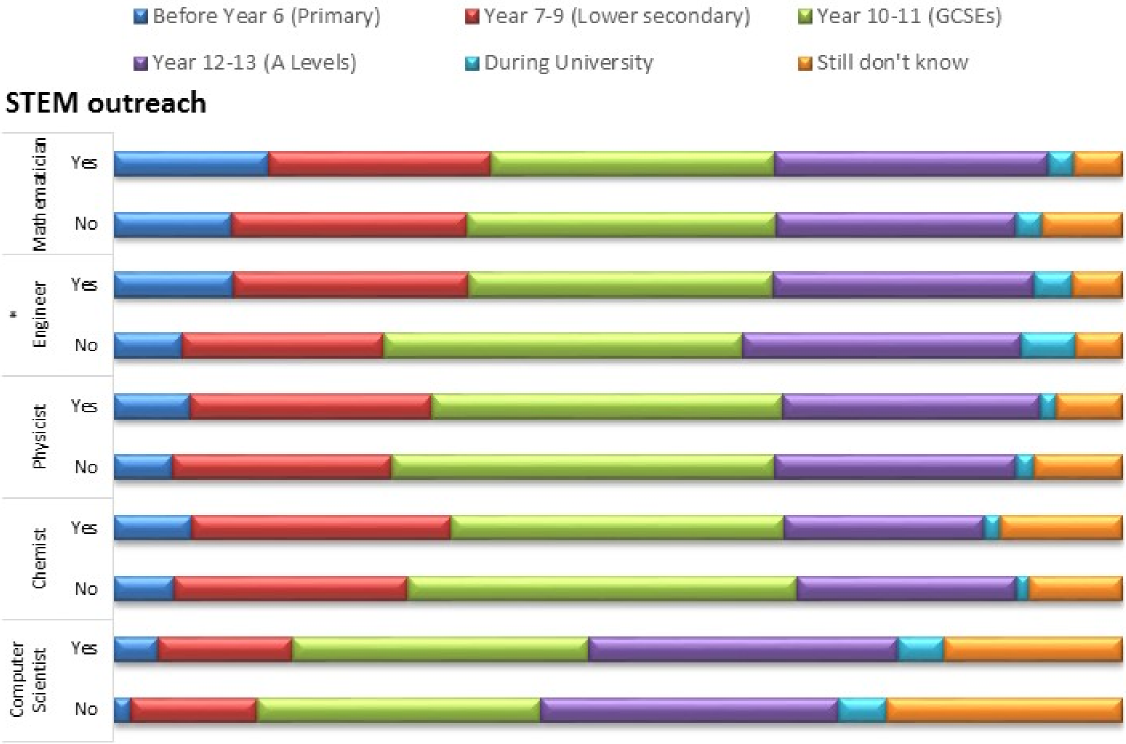

Figure 6.39: The association between students' academic stage of career awareness with participation in STEM outreach activities

The results summarised in Table 6.23, display the p-values calculated from a chi-squared test and Fisher's exact test based on the association between students' academic stage of understanding STEM careers and the variables: gender and students engagement with STEM outreach.

	Mathematician	Engineer	Physicist	Chemist	Computer Scientist
Gender	0.447	0.002**	<0.001***	0.036*	0.058
Ethnicity	0.145	0.161	0.222	0.254	0.153
STEM outreach	0.341	0.026*	0.814	0.628	0.051

Table 6.23: Statistical differences based on the academic stage of understanding STEM careers and students from different gender, ethnicity and STEM outreach participation, and; Key: * p<0.05; ** p<0.01; *** p<0.001

The above figures show that students’ academic stage of awareness on each STEM profession differed when analysed according to gender. Evidence of a statistical association was found between the academic stages of understanding what engineers, physicists and chemists do and gender ($p=0.002$, <0.001 and 0.036 respectively, chi-squared tests). Nevertheless, a larger proportion of females expressed uncertainty about familiarity with careers associated with computer science (28%) than males (21%), although the association between gender and academic stage of awareness was only marginally significant ($p=0.058$, chi-squared test).

A significant association was found between a student’s awareness of careers in engineering and whether or not they had participated in a STEM outreach activity ($p=0.026$, chi-squared test). It appears many such students become aware of what engineers do earlier in their academic progression than those who had not participated. There was also evidence to suggest that participating in STEM outreach positively influenced students’ responses to what a computer scientist does, though the association was marginally significant ($p=0.051$, chi-squared test). Thus, impact of STEM outreach was shown as the findings demonstrated that those that engaged in the activities were more aware at an earlier stage of the career progressions related to STEM than those that had not.

6.5 Overview and comparison of views from students studying in different academic years

An overview is now presented detailing the responses that were provided by students studying across the three educational stages. Along with summarising key trends, factors are explored that influenced GCSE and A level students’ aspirations for a career in STEM. Further, qualitative responses outlining students’ perceptions of STEM are discussed along with key suggestions that can encourage more students to study STEM subjects at higher education.

6.5.1 Suggestions for improving GCSE, A level and STEM undergraduate student's STEM outreach experience

Figure 6.40 summaries GCSE, A level and STEM undergraduate students' recommendations on the areas they considered required addressing for future STEM activities.

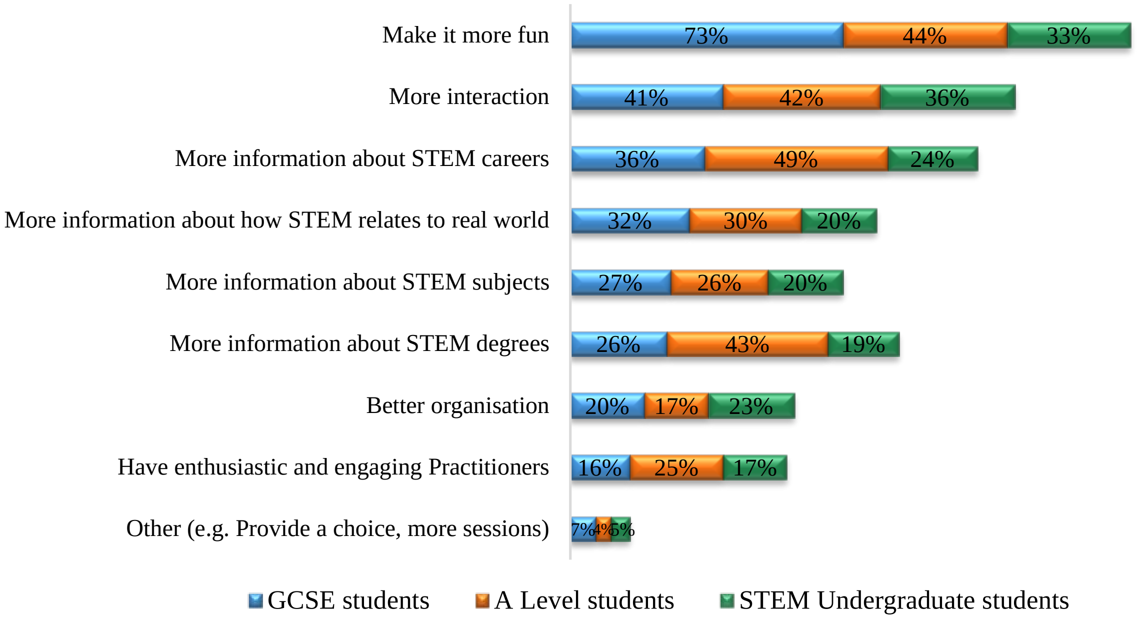

Figure 6.40: Suggestions for improving students' experience of STEM outreach

The findings detail similarities from the responses provided by GCSE, A level and STEM undergraduate students as well as key preferences based on their current academic stage.

Although the level of interaction experienced can vary dependent on the nature of the activity, student interaction between outreach practitioners, teachers, university students and with employers can contribute and add value towards students mode of learning (National HE STEM Programme 2010; Straw and MacLeod 2013). In the results from this current study, all three groups of students identified this as a key element for future improvements. Thus, it shows GCSE, A level and STEM undergraduate students would have preferred greater interaction. These views should be taken into account when planning future outreach activities.

Further, it appears the younger students particularly would have preferred their experience to be more enjoyable (73%). Comparing results for GCSE results and A level students, information on careers (49%) and degrees (43%) was important to A level students, whereas 23% of the undergraduate students wanted to ensure that events were better organised.

Although it appears that the student responses varied according to the age of the students, their feedback is critical and should be taken into consideration to ensure students' future outreach experience is better, improved and more impactful.

Most STEM outreach practitioners say that designing activities to be enjoyable is very important. One way of doing this is by building in interactivity (see section 4.12). However, irrespective of educational stage, a large proportion of students identified "more fun" and "more interaction" as key ways to improve outreach. This is reflected in some of the types of activities that feature far more often as least preferred than as most preferred. This suggests that practitioners are not addressing the aims of enjoyment and interactivity as effectively as they believe they are. This view is reinforced by the accounts of the teachers who recount many instances of too much talk and PowerPoint and not enough hands-on time (see section 5.6).

6.5.2 Key influences on GCSE, A level and STEM undergraduate students' course choices

The key factors that influence GCSE, A level and STEM undergraduate students' post-16, post-18 and university course choices are detailed in Figure 6.41.

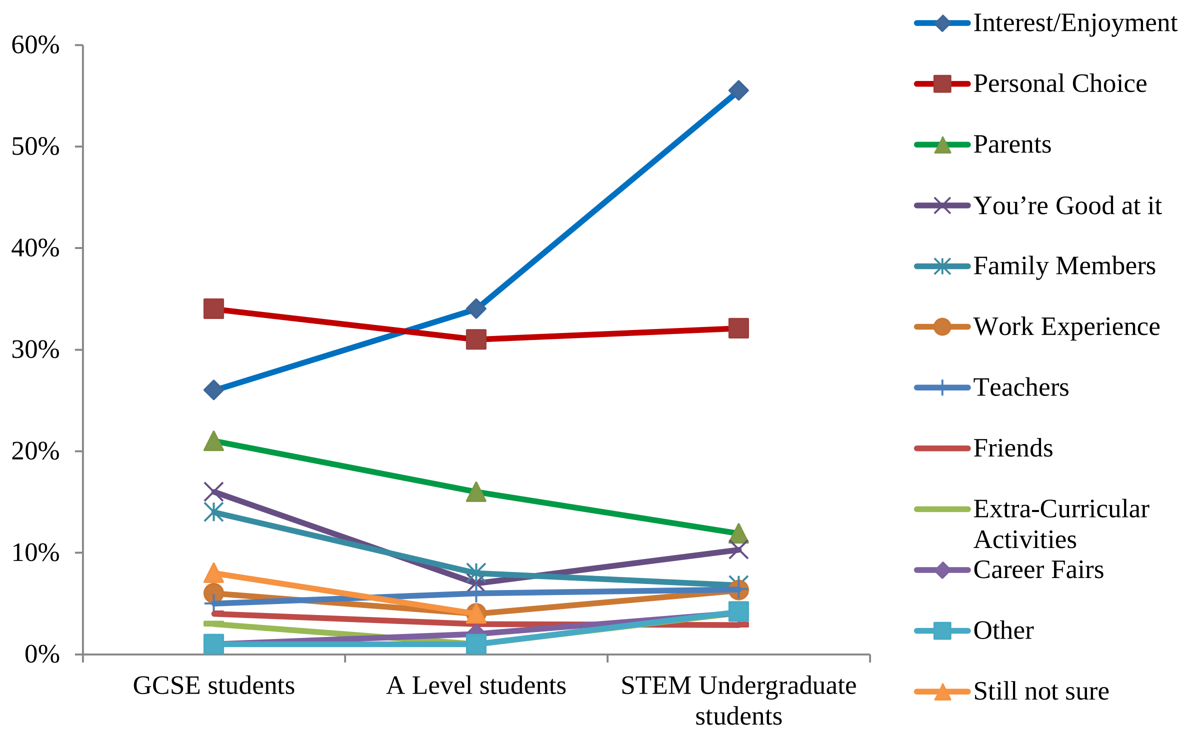

Figure 6.41: Factors influencing GCSE, A level and STEM undergraduate student’s decision-making process (the lines are only to guide the reader)

Figure 6.41 displays the number of responses (%) each student provided. The above trend shows the variation within the sample of students and it can be observed that there is great significance towards the level of interest and/or enjoyment a student develops for a subject during each transition point. It displays that the older the students were the more likely they were to consider their decision based on this factor. Hence supporting the research findings by Blenkinsop et al. (2006), who considered influences that motivated students and categorised enjoyment of a subject as an “intrinsic” factor. Springate et al. (2008) in their findings labelled enjoyment as a “high-influence factor” for choosing physics or chemistry at degree or A level.

For this current study, the undergraduate students were twice as likely as GCSE students to select their course because of their interest and/or enjoyment. The proportion of students that indicated a personal preference as their key factor was similar across students from the three academic stages, and this was the most common reason selected by GCSE students. In addition, GCSE students viewed as important factors such as parents/family members supporting their decision-making process, which confirms findings from Blenkinsop et al. (2006). Nevertheless, the results from this current study show that as the students' progress through the different transition points, the importance of parents/family members reduces as a key source of influence. Many studies have emphasised how the lack of parental understanding and awareness of careers can impact students' subject and career decisions (Springate et al. 2008; IET 2008; Archer 2013). Thus, focusing on students' as well as their parents' awareness and knowledge on the range of opportunities that open with a STEM qualification helps to prepare students of all ages to make an informed decision on the subjects they choose during their educational journey.

The findings here are consistent with young people 'growing up'. At younger ages, they are less sure of themselves and parents and family have a greater influence. However as they get older their personal identities become more firmly developed and so the influence of their interest and enjoyment increases remarkably whilst that of parent and family declines (National Union of Students 2011; Nugent et al. 2015).

6.5.3 Impact of STEM outreach on GCSE, A level and STEM undergraduate students' understanding of STEM subjects

The figures below illustrate the differences outreach has made towards students expressing their understanding of STEM subjects. Figure 6.42 shows for those that participated in STEM outreach, the percentage of students at each stage who said they did not understand the subject at all (i.e. response scoring 1). Figure 6.43 shows for those that did not participate, the percentage of students at each stage said they did not understand the subject at all (i.e. response scoring 1).

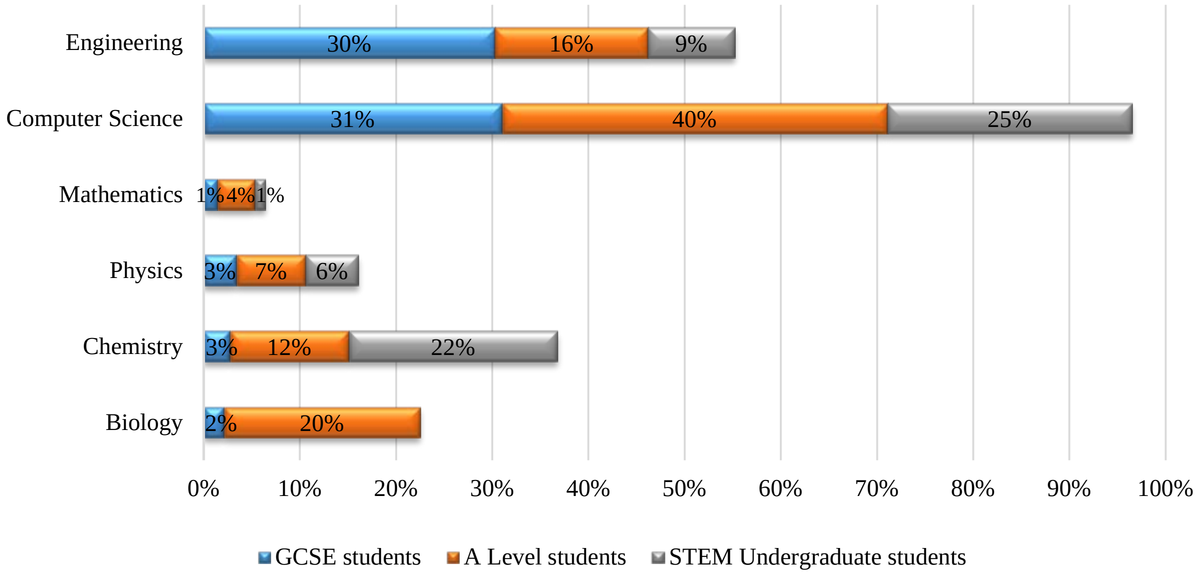

Figure 6.42: Students participated in STEM outreach and stated “not at all”

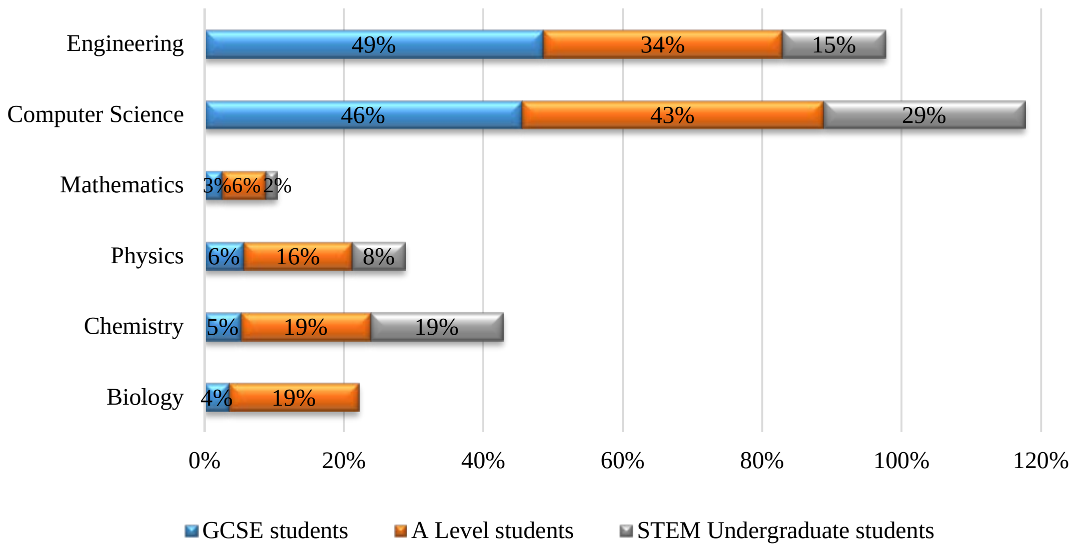

Figure 6.43: Students did not participate in STEM outreach and stated “not at all”

Please note: STEM undergraduate students were not asked about biology.

Although the impact of outreach appears to be positive, the results highlight a concern, as students at all levels on average showed a very low level of understanding of the subject computer science. The Royal Society (2012) have expressed concern about the lack of understanding school pupils have towards computer science. Together with engineering, this subject area is particularly facing a shortage of graduates. Data from HEFCE (2015) have highlighted the negative shortfall in the number of students graduating with computer science degrees and further detailed figures that show over an eleven year period (2002-03 to 2013-14) entrant numbers have fallen by more than a third (77,527 to 47,468 undergraduate students). BCS (2007) have also echoed their concern regarding this issue and in 2006, Professor Nigel Shadbolt, the then President of the Society, told BBC News “the computer industry faces a skills crisis” (Ghosh 2006). In addition, another commonly expressed concern is the misunderstanding of various terms that come under the umbrella term computing (The Royal Society 2012).

Until 2012 ICT was taught as a mandatory part of the English Key Stage 2 and 3 curriculum and was an optional subject at Key Stage 4 and 5. A new computing curriculum for England was introduced in September 2014, to be applied from primary level upwards. Under the subject computing, young pupils are now able to experience aspects of computer science, information technology and digital literacy, understanding how to design and write computer programmes, how a computer system works as well as how computer are used (Computing at School 2012).

However, although this has been viewed as a major step towards exposing pupils from a younger age to key elements of computer science, the Select Committee on Digital Skills (2015) outlined skills deficit faced by some teachers tasked with delivering the new curriculum.

Although this recent change in the area of computing is a very positive development, the effect of the curriculum change is not reflected in the results from this current study, because data were collected prior to and during the curriculum reform and implementation.

6.5.4 Aspiration of a STEM career of GCSE and A level students

As well as supporting students' attitudes, preconceived ideas, understanding, knowledge and confidence in their ability to "do" STEM subjects, a key agenda of STEM outreach ultimately has been to raise young people's aspirations to pursue a career in STEM (Mann and Oldknow 2012). The GCSE and A level students were questioned on whether they aspired to a STEM career or not. The undergraduate students were not questioned about this because they had already chosen their degree subjects and therefore demonstrate a strong direction and interest towards a career in STEM (see Figure 6.44).

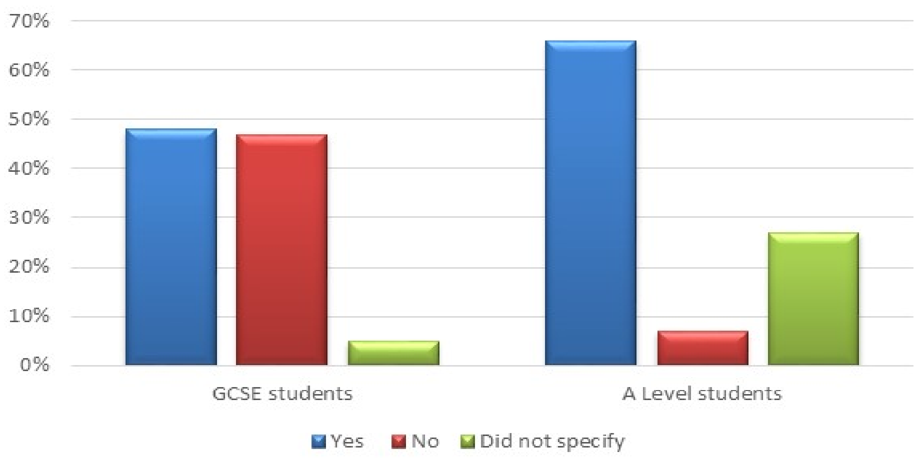

Figure 6.44: GCSE and A level student's aspiration for a career in STEM

Research by ASPIRE has found that although young pupils aged 10 to 14 value science, many hold a strong view that "science is not for me" (Archer 2014). The knowledge that young people, as well as family members, have at the range of career opportunities from a STEM qualification is very limited, thus negatively affecting the proportion of students that strive towards a career in STEM (Institute of Physics 2014; Archer 2014).

A possible reason why there are more positive responses from A level students from this current study considering a STEM career perhaps can be explained by how the data were collected. Of the sample, data from 207 A level students was collected from eight schools/colleges studying various A level subjects and the remaining sample of 258 students was collected by attending six events held at universities. Here, the events held at universities ranged from general university to STEM specific events. Although the latter type of event may have influenced the composition of the respondents, overall the sample in this study represents students from a wide range of backgrounds and interests.

To further explore the GCSE and A level responses, the differences within those seeking to pursue a career in STEM based on gender, ethnicity, given careers advice, participation in STEM outreach and students' rate of engagement with outreach activities is detailed below (see Figure 6.45 for results from GCSE students and Figure 6.46 for results from A level students). In order to understand the differences between each association, i.e. gender and those aspiring to a career in STEM, the appropriate statistical tests were used (chi-squared test or Mann-Whitney U test).

The results indicate strongly significant evidence of an association between gender and the proportion of students aspiring to a career in STEM amongst the two groups of students ($p<0.001$ and 0.036 respectively, chi-squared tests). The findings showed that 61% of GCSE male students and 93% of A level male students aspired to a career in STEM compared to 43% and 86% of GCSE and A level female students respectively.

The gender imbalance that is present in subjects and careers associated with STEM has been reflected throughout the findings and is also shown here, with a considerably greater proportion of males indicating interested towards pursuing a career in STEM than the females. Although these results are not surprising, this reinforces the current message there is an urgent need to focus from an early age on increasing girls' enjoyment, interests, understanding, awareness as well as aspirations to pursue a career in STEM.

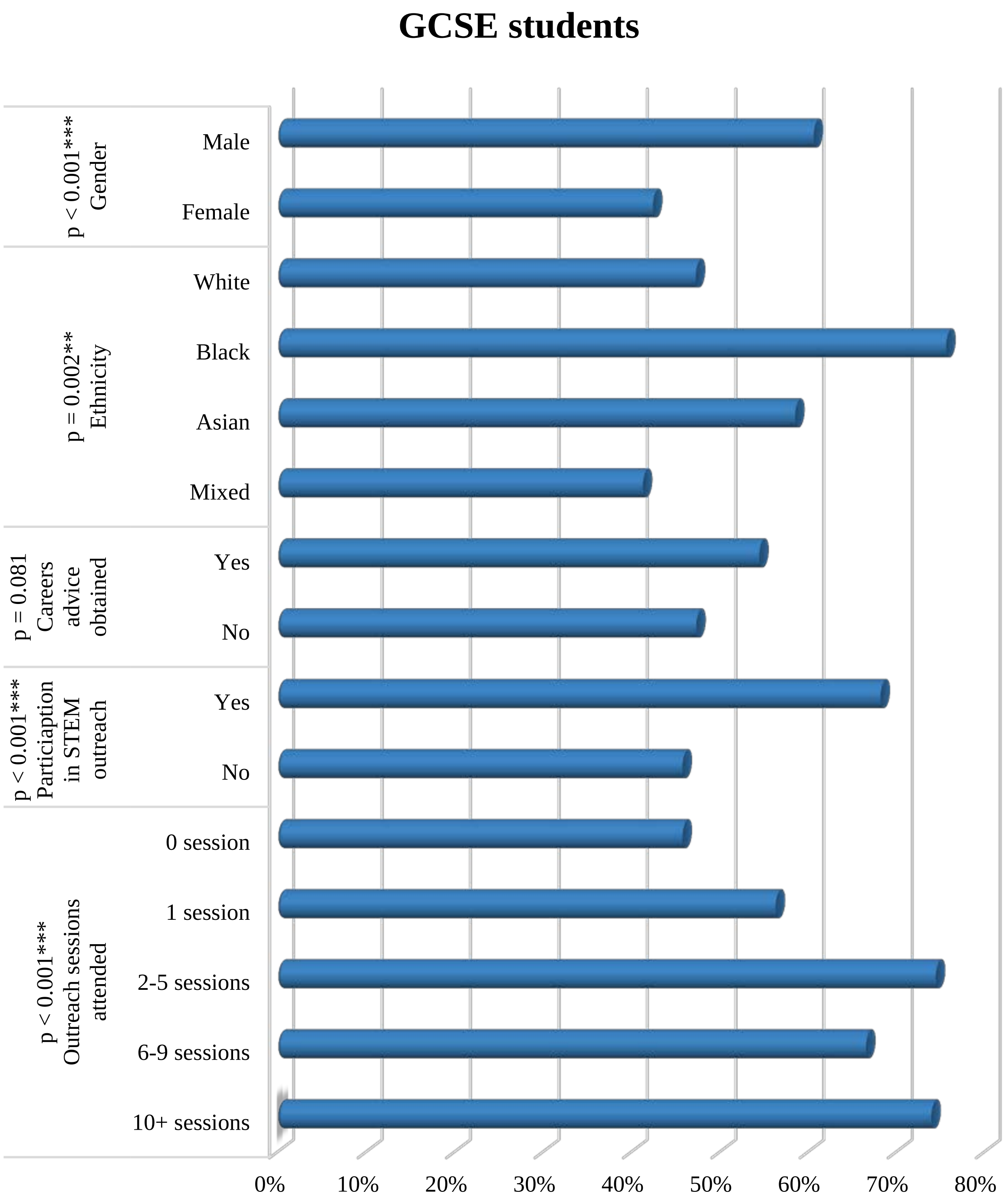

Figure 6.45: Based on each factor, the proportion of GCSE students aspiring to a career in STEM, and; Key: * p<0.05; ** p<0.01; *** p<0.001

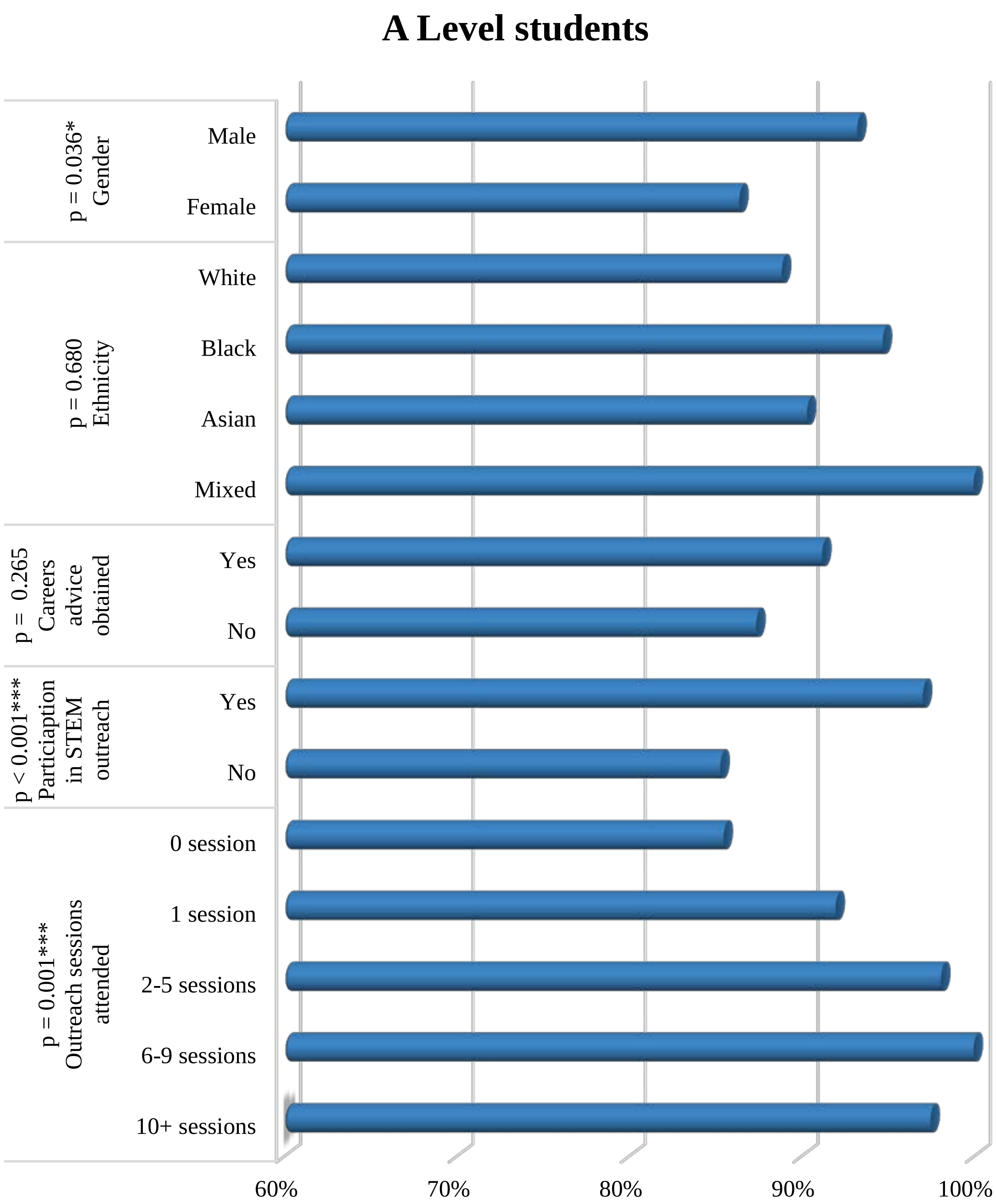

Figure 6.46: Based on each factor the proportion of A level students aspiring to a career in STEM and; Key: * p<0.05; ** p<0.01; *** p<0.001

The disassociation with STEM was also apparent in the analysis based on different ethnic groups, and again a similar observation was found amongst the GCSE and A level students. Those that are underrepresented (Black and Asian students) in STEM were overall more likely to aspire to follow a career path in an area of STEM than White students and this was statistically significant amongst the GCSE students ($p=0.002$, chi-squared test). A recent review by WISE (2014) detailed figures presented by HESA (2011/12) showing differences in study choices analysed according to ethnicity, indicating specifically that Black and minority ethnic groups on the whole are more likely to study STEM subjects beyond GCSE than other ethnic groups (Macdonald 2014).

Another area investigated was comparison of responses about aspiring to a STEM career and students obtaining careers advice, participating in STEM outreach and their level of engagement with STEM outreach activities.

For both groups of GCSE and A level students, obtaining careers advice did not significantly influence this decision ($p>0.05$ for both respectively, chi-squared tests), though the proportion of those that received careers advice were slightly more likely to show an interest towards pursuing a career in STEM (55% and 91% respectively) than the proportion of those that did not receive careers advice (47% and 87% respectively). Studies have outlined how many pupils lack high quality guidance to support their career decisions (Sainsbury 2007; Ofsted 2011; Kumar, Randerson and Johnson 2015). Thus, despite this not having a significant effect towards students' career aspirations, it most certainly reflects that the potential high quality careers advice can influence students' career aspirations.

The findings showed that there was very strong significant evidence of an association between the proportion of students aspiring to a career in STEM and whether or not they had participated in STEM outreach activities ($p<0.001$ and <0.001 for GCSE and A level students respectively, chi-squared tests). Equally, student responses differed based on the level of interaction they experienced with STEM outreach activities ($p<0.001$ and 0.001 for GCSE and A level students respectively, Mann-Whitney U tests). Those that were given the experience of outreach were significantly more likely to indicate a greater response of following a career path in an area of STEM than those not given this experience. Additionally, those involved in a range of opportunities (student participation in more than one outreach event) were also significantly more likely than their peers to be interested in pursuing a career in STEM. Hence, the results show a positive impact and indicate STEM outreach has made a strong contribution towards encouraging young pupils to pursue a career in STEM.

The above factors appear to significantly affect the likelihood of a GCSE and A level student aspiring to a career in STEM and, therefore, this has further been investigated through a binary logistic regression model. Through this approach the relationship between students aspiration for a STEM career is described (where yes is for a career aspiration in STEM and no is otherwise) and the probability of this occurring will be predicted by using the variables gender, ethnicity, careers advice given and level of engagement students showed towards STEM outreach. Thus, using the given conditions, the probability of predicting GCSE and A level students aspiring to a career in STEM based on the independent variables is explored in Tables 6.24 and 6.25.

The output from a binary logistic regression for predicting the likelihood of GCSE students aspiring to a career in STEM is shown in Table 6.24.

	B coefficients	Odds Ratio Exp (B)	p-value
Intercept	0.108	1.114	0.540
Gender (reference category = Male)	-0.876	0.416	<0.001***
Ethnicity (reference category = White)			<0.001***
Black students	1.468	4.342	0.001***
Asian students	0.559	1.749	0.013*
Mixed students	-0.429	0.651	0.312
Careers advice given (reference category = no)	0.206	1.229	0.269
Number of outreach sessions attended	0.405	1.500	<0.001***
Overall percentage correctly classified	63.9%		
R^2 (Nagelkerke)	0.145		
Model chi-squared	p<0.001***		
Hosmer and Lemeshow Test	p=0.056		

Table 6.24: Results from the binary logistic regression for GCSE students and; Key: * p<0.05; ** p<0.01; *** p<0.001

The regression function for predicting the likelihood of GCSE students aspiring to a career in STEM is:

$\ln\left(\frac{p}{1-p}\right)$ = 0.108 - 0.876 (if Female) + 1.468 (if Black) + 0.559 (if Asian) - 0.429 (if Mixed) + 0.206 (if Careers advice gained) + 0.405 Level of participation in STEM outreach,

where p is the probability of GCSE students aspiring to a career in STEM

Overall this was found to be a significantly useful model ($p<0.001$, chi-square test) and a good fit to the data ($p=0.056>0.05$, Hosmer and Lemeshow test). The model explained 15% (Nagelkerke R^2) of the variance in GCSE students' likelihood of aspiring to a career in STEM, and 64% of cases were correctly classified. Using the Wald statistic, the significance levels of each coefficient are given in Table 6.24 and the results show that gender (p<0.001***), ethnicity (p<0.001***) and students level of participation in STEM outreach (p<0.001***) contributed significantly to the model but gaining careers advice (p=0.269) did not. Table 6.24 shows that females were almost 60% less likely to display career aspiration in STEM than males and that Black and Asian students were 4.3 and 1.8 times more likely to aspire to a career in STEM than White students. The results also show that for GCSE students, participation in STEM outreach is 1.5 times more likely for a student aspiring to a career in STEM than others ($p<0.05$). Receiving careers advice was associated with an increased likelihood of pursuing a career in STEM but this was not significant ($p>0.05$).

The output from a binary logistic regression for predicting the likelihood of A level students aspiring to a career in STEM is shown in Table 6.25.

	B coefficients	Odds Ratio Exp (B)	p-value
Intercept	1.773	5.890	<0.001***
Gender (reference category = Male)	-0.856	0.425	0.037*
Ethnicity (reference category = White)			0.576
Black students	1.119	3.062	0.162
Asian students	0.228	1.256	0.586
Mixed students	19.398	26568231	0.999
Careers advice given (reference category = no)	0.500	1.648	0.209
Number of outreach sessions attended	0.687	1.989	0.006**
Overall percentage correctly classified	90.4%		
R^2 (Nagelkerke)	0.143		
Model chi-squared	p=0.001**		
Hosmer and Lemeshow Test	p=0.420		

Table 6.25: Results from the binary logistic regression for A level students and; Key: * p<0.05; ** p<0.01; *** p<0.001

The regression function for predicting the likelihood of A level students aspiring to a career in STEM is:

ln $\left(\frac{p}{1-p}\right)$ = 1.773 - 0.856 (if Female) + 1.119 (if Black) + 0.228 (if Asian) + 19.398 (if Mixed) + 0.5 (if Careers advice gained) + 0.687 Level of participation in STEM outreach,

where p is the probability of A level students aspiring to a career in STEM

Similarly to the GCSE results, this was overall found to be a significantly useful model (p=0.001, chi-square test) and a good fit to the data (p=0.420 >0.05, Hosmer and Lemeshow test). The model explained 14% (Nagelkerke R^2) of the variance in A level students likelihood of aspiring to a career in STEM and 90% of cases were correctly classified. Using the Wald statistic, the significance levels of each coefficient are given in Table 6.25 and the results show that gender (p=0.037*) and students level of participation in STEM outreach (p=0.006**) contributed significantly to the model, but gaining careers advice (p=0.209) and students responses based on their ethnicity did not (p=0.576). Table 6.25 shows that females were 57% less likely to display career aspiration in STEM than males and that increased level of participation in STEM outreach is almost twice as likely to influence the likelihood of a student aspiring to a career in STEM than others. Receiving careers advice and students responses for different ethnic groups compared to White students were associated with an increased likelihood of pursuing a career in STEM, but these were not significant (p>0.05).

Please note: although the results in Table 6.25 shows a higher odds ratio for certain ethnic groups aspiring to a career in STEM than White students, the sample for some categories represented a small proportion of students, which perhaps has affected the odds ratio output calculated above. The GCSE Black and Mixed ethnic category consisted of 34 and 33 students respectively and A level Black and Mixed ethnic category was 48 and 19 students respectively.

Research by ASPIRE investigated how younger students, aged 10 to 14, build science aspirations and career choices (Archer 2013). Their key findings were “girls are less likely than boys to aspire to science careers even though a higher percentage of girls than boys rate science as their favourite subject”. They also found Asian students were more likely to aspire to a science career and that negative science views were not the problem amongst young people forming these aspirations, though the amount of ‘science capital’ in a student’s family certainly was. The current study which focused on students aged 14 to 19 has also found that girls are less likely than boys to aspire to a career in STEM, and similarly GCSE Asian as well as Black students were more likely to pursue a career in STEM than GCSE White students. This study has further found that the opportunity for students to participate in outreach significantly contributed towards increasing GCSE and A level pupils’ aspiration in STEM.

Thus, to support the likelihood of increasing the pipeline of students interested and engaged towards pursuing a career in STEM, outreach experience should be provided to young students during their educational journey, such that the higher the level of engagement students receive, the higher the likelihood of influencing GCSE and A level students' STEM career aspirations. Further, the results show that it is essential to engage students from a White ethnic background as well, not just those ethnic groups that are underrepresented in STEM. In addition, as previous studies have outlined, this current study emphasises how a large proportion of girls still need to be inspired towards developing an aspiration to pursue a career route in STEM.

6.5.5 GCSE and A level students' perception of STEM

GCSE and A level students had a shared viewpoint on four key areas of STEM; science, mathematics, engineering and computing/technology. Students' comments overall provided a better understanding of their perception and outlined a general overview of STEM subjects and careers. Also throughout, differences, as well as similarities amongst the two groups of students, were found and this was across those that were and were not aspiring to a career in STEM (see Table 6.26 and 6.27 for selected student comments). GCSE and A level students commonly shared a greater level of awareness towards the importance of science and mathematics. For example, GCSE pupils stated that *"science is forever increasing the understanding of everything we know"* and that it is *"important for nearly all jobs"*. Similarly, A level students expressed *"it's a way to understand and see the world from different perspectives"* and *"science is that what attempts to describe everything based on evidence. The closest thing to truth we have"*.

These comments show a level of appreciation towards the significance of science from both age groups of students. A wider relevance towards the subject mathematics was also shown. For instance, GCSE students stated *"many careers are involved around it"* and that *"maths helps us in the future to provide opportunities"* and views by A level students were *"maths is a universal language, I like that anyone can study it" and that it is "fascinating because everything has maths behind it"*.

However, although GCSE and A level students overall viewed this as a useful subject, students wanted to know more about how mathematics was used in various jobs. The connection between the subject and careers seemed slightly obscure and both (sixth-form students more) expressed uncertainty as to how mathematics as a subject and degree could be transferred into a career.

The students' general understanding of this area, on the whole though appeared positive as comments from GCSE and A level students were, *"when applied, maths is an interesting subject"* and *"I like how everything is derived from maths"* and that *"I like how I need to engage and concentrate in this subject"*, supporting the findings from the earlier sections as students better understood what mathematics is than the other subjects.

The GCSE students in particular shared their views towards teachers, which were diverse and ranged from *"I enjoy it with the right teacher"* or that *"it is good, the maths teachers really help"* or *"I used to enjoy maths a lot but my teacher put me off"*. GCSE students also detailed their views in relation to different aspects of teaching and on many occasions emphasis of gaining clearer explanations were made. A few also expressed that they often get taught the boring aspects leading to them finding science less interesting. Further many GCSE and A level students collectively indicated how much they enjoyed experiments and that their practical involvement contributed towards increasing their level of interest and enjoyment to science.

The students' views from this current study echo research findings by the Wellcome Trust (2011), as they also found pupils aged 16 and above enjoyed their engagement in experiments. Their qualitative analysis overall conveyed an important message, which was that students appreciated learning through practical lessons and this experience was often more easily remembered than the content learnt from theory later on in life.

The results from this current study also observed students' views towards engineering and computing. For this particular question, the term computer science was not used in the hope that it encouraged more students to respond and share their outlook on this area of STEM.

GCSE students' comments towards engineering were that *"it is amazing how much work is involved in producing very simple things"* and that this is "*important for future" and "useful because engineers have built and designed all the man-made creations"*. Similarly, A level students stated *"engineering brings the logic in maths to reality"* and that "*it's just related to everything, nothing could be made without engineers"*.

There was a general agreement that engineering was relevant, though those that indicated an interest towards aspiring to a STEM career were on the whole more expressive towards enjoying and finding this exciting than those that were not interested in a career in an area of STEM.

GCSE students also showed a level of awareness of the future opportunities that arise from engineering, for instance a response was *"decent pay"*, though comments were also made that illustrated their lack of knowledge of careers associated with engineering. For example, *"I'm not sure about careers that are into this"*. Both groups of students enjoying engineering or having a lack of interest and understanding was shown. Students' unfamiliarity was detailed and some further attributed this to arise because they had not been taught this subject through school.

Although overall both groups expressed less awareness towards engineering, some of the GCSE students in particular outlined a preconceived view which was that this was not for them. For instance, comments such as *"I don't know a lot about it, but I don't think that it's me"* and "*I don't know anything about it and I don't like the look of it"* were made. Hence, it suggests many pupils had disconnected themselves from pursuing an engineering route despite not knowing what this is about, supporting the findings from the report "*Not for people like me?*" by Macdonald (2014). The study by Macdonald (2014) expressed a similar outlook and stated how this view is commonly held, especially from those that are underrepresented in STEM.

The image problems known to be held by students in general emerged from the results from this current study, with comments such as *"it's mostly for boys"* and *"it's too* *technical"* and that you *"have to be clever"* were expressed by respondents within both GCSE and A level groups. As well as holding a bias view of engineering, many sixth-form students, whilst noting their view, used terms such as *"it seems", "I think", "I hear" or "I understand"* showing a level of uncertainty and lack of awareness about the true nature and diversity of engineering.

Some students related their perceptions with reference to a family member (e.g. my dad and brother also work in the field) and others demonstrated deeper knowledge of engineering, for example *"I enjoy finding out how things are made and taking them apart"* and *"this is my favourite area since it is a combination of maths, science and design"*.

Similar responses from the GCSE and A level students were provided towards computing/technology, and it appeared many students described their view on this by referring to the term computing as a synonym for personal computers, ICT (e.g. spreadsheets) or computer science (e.g. programming and coding). Positive views on the relevance and usefulness of using computers were expressed and a level of appreciation towards technology was shown. For instance, students' comments stated that it is *"extremely interesting that technology is constantly improving. Everything depends on technology"* and this *"helps improve/invent more communication" and is "the way forward"*.

Views on this area of STEM, however, were also obscure and many students detailed they did not know and had no interest in computing other that knowing how to use it for basic needs. Despite many students noting uncertainty, some students expressed interest, for example: *"…but I would love to learn more"*. Curiosity was shown amongst both age groups and some respondents showed an interest in gaining experience of computer science during school (see Tables 6.26 and 6.27 for selected GCSE and A level student responses provided for each subject and whether or not they aspired to a career in STEM).

GCSE students view towards Science

Aspiring to *a STEM career*	*Aspiring* to *a non-STEM career*
"I enjoy it as it gives me broader knowledge of things" "Science is forever increasing the understanding of everything we know" "Important for nearly all jobs" "Really enjoy it and I want a career in the future to do with it"	"It's amazing how you can learn more about the earth and outer space. Makes you wonder about life"
"It's fun and enjoyable" "When I come across new things I find them very interesting" "I find it interesting and wish to carry it on with A levels" "It's interesting but difficult"	"Interesting, and want to learn more" "Interesting when made fun" "Fun but gets really hard"
"I don't really enjoy science" "Not engaging" "I find it hard to understand" "Can be boring"	"Don't understand it" "It's quite boring and not for me" "Hard, hard, hard" "Interesting but I am not interested in the careers that it leads up to"
"Biology and chemistry are really boring, physics is maths with meaning" "Biology is quite easy however physics can be a bit challenging" "Biology is really interesting to find out how life forms work. Chemistry is quite interesting because you can link it to biology. Physics is good but have lost interest in it because my teacher just gives us sheets" "I only enjoy biology because I find it interesting, chemistry and physics confuse me"	"Biology is the only one that I find interesting and engaging and despise the other sciences" "Can be really interesting depending on what interests you. Find the biology side of science more interesting than the physics because it's easier to understand" "I don't like physics or chemistry however I find learning about my own body in biology interesting" "Physics and chemistry are great, but biology is not interesting to me"
"I struggle but once I am taught properly I really enjoy" "It is hard until you have it explained" "It is a very interesting subject, but the way we are taught it makes it more boring" "The science teachers need to help more" "Science is okay, can be boring and isn't explained how it's useful"	"I find it very boring and hard to remember as I don't enjoy the lesson" "I'm not good at it and therefore don't like it" "School makes it appealing" "I understand it very well, teachers help so much" "The teachers don't help at all" "Could be better if we didn't use textbooks"

	“I think this is a good subject but I think that they teach the boring aspects of science”
“A bit interesting but mostly when we do an experiment” “Chemistry is interesting. I enjoy doing practical work” “Can be interesting or boring depending on whether doing experiments or not”	“Interesting mostly when completing experiment” “Boring unless doing experiments” “Boring but can be fun with practicals” “Experiments can be fun” “It’s very interesting when we do practical work”

GCSE students view towards Mathematics

Aspiring to *a STEM career*	*Aspiring* to *a non-STEM career*
“Always needed! There is not a day where maths isn't needed” “You need maths in a lot of other subjects too, it is useful and helpful to have maths skills” “Gives you the skills for other areas of the STEM subjects” “Best subject for my future career” “Many careers are involved around it” “Fun and interesting, would like to pursue a career in it”	“Maths helps us in the future to provide opportunities” “Useful” “I do not know how this subject will help me in the future” “Would like to know more maths involved in jobs” “It's ok, a good challenge but wouldn't pursue it as a career”
“I like this because I know it well and understand it” “I love maths and think we should do more active activities” “The thrill of getting the answer” “Best subject ever” “Maths is great and complex but even though it takes a lot of effort it is still fun” “I love the excitement you get when you finish a question”	“I started to enjoy maths when I understood it more in my GCSEs” “I like how I need to engage and concentrate in this subject” “Fun to get questions right. Challenge!” “I struggle a bit with maths but always try my hardest to get my grades in maths”
“Boring but a main GCSE” “Boring but I still am determined” “Useful yet boring” “I think I have a lot of skills in maths when I was in primary school now I find maths very easy in secondary school” “Maths is very boring and can be very hard”	“Learning stuff you will never use” “Found it good until I hit year 9 and I don't like it that much now” “I don't know that much” “Good at it but it doesn't interest me” “Boring and useful” “I don't enjoy it”
“It is hard until you have it explained” “Good, the maths teachers really help” “I enjoy it with the right teacher” “I use to enjoy maths a lot but my teacher put me off”	"Boring/Boring teachers” “I enjoy different skills, teachers help a lot”

GCSE students view towards Engineering

Aspiring to *a STEM career*	*Aspiring* to *a non-STEM career*
“Decides which way the future is and massively affects the historic era” “Is useful because engineers have built and designed all the man made creations” “It is amazing how much work is involved in producing very simple things” “Coming up with new ideas”	“Learn to build and create new things” “I find it fascinating how people can produce wonderful things” “Important for future”
“Decent Pay” “Good for getting a steady career path” “A career for the future as I find it interesting and it ties maths and science together” “Interesting and good to learn about for future careers” “Fun to do sometimes, but not very entertaining career” “I'm not sure about careers that are into this”	-
“This should not be a male dominant job” “It's mostly for boys” “Car designing?” “Too technical” “Don't really know, something cars”	“It's a man's job” “Nuts and bolts/builders” “Cars” “If it’s about cars then I like cars” “It's too technical”
“You get to make new and strange new things :)” “I am fascinated by how things work and how much you find out when you take things apart” “Fun, my hobby” “I enjoy finding out how things are made and taking them apart” “Making, designing and evaluating I just love, particularly design and making” “It’s enjoyable and fun to do” “It's experimental”	“Fun to do and interesting” “Ok I guess” “Boring! Cool what they create though” “Hard work” “Good field of work”
“I think that this is interesting but we do not do this at school” “Haven't been taught this subject” “I don't know anything about it” “I don't know a lot about it, but I don't think that it's me” “Never done it and not really interested” “Don't care much”	“Could be quite fun” “Could be interesting but I've never looked into it” “I don't know anything about it and I don't like the look of it “ “It doesn't seem interesting” “I don't know much about it but it doesn't interest me” “Have no idea what it is and have absolutely no interest whatsoever”

	“I've never done any engineering so I obviously know nothing about it“ “Not done engineering as a lesson”
“I find it very interesting and it exercises maths and physics which are my best subjects (My dad and brother also work in the field)” “My family member is an engineer (civil) however I would like to go into a different type of engineering”	“My dad does it, seems okay”

GCSE students view towards Computing/Technology

Aspiring to *a STEM career*	*Aspiring* to *a non-STEM career*
"Helpful to daily life" "Helps society function" "Helps improve/invent more communication" "Computing/Technology is a must have skill for the world we live in today" "As the world is going forward with technology, careers will go with it" "Good skills to learn as the world is largely technologically based" "Most jobs use computers in some ways" "Despite it being challenging, it's enjoyable. It's essential as technology is developing"	"The way forward" "Useful"
"Really interesting would like to go into a career in it"	"I like doing it and am good at it but I don't like careers"
"I'd like to try it" "Was fun in KS3 but now I don't do any of it" "Don't know. Guess it's hard and technical" "I don't do much of this so I am not educated enough to be interested" "I can use a computer and that's all I need to know" "I have no interest in this other than how to work basic technical appliances at home" "Don't care"	"I don't know much about it but I would love to learn more " "I do not know very much about this but I'm intrigued to know" "It doesn't interest me although it would probably be useful" "I know a fair amount could probably know more if I tried" "I don't know much about it but it doesn't interest me much"
"I'm interested in building up computers and programming things" "I like programming and it is interesting to see how code works" "I like technology, and therefore find it interesting" "Interesting (very), I really like learning how to programme etc" "A very interesting subject that I enjoy" "It's fascinating when you learn about how codes work and how to build new tech" "I like how so much work goes into coding" "I find this extremely exciting as you find out about old and new technology" "Coding is a fun past time and the whole world is going to be revolved around technology"	"Can be quite boring but makes a lot of sense as it's quite simple" "I enjoy technology because I enjoy practical things" "I enjoy computing because I find electronics interesting and cool and like learning more about it" "Fun as practical" "Gaming/computer/software programming" "Interesting, I love programming"

Table 6.26: GCSE students' views on science, mathematics, engineering and computing/technology

A Level students view towards Science

Aspiring to *a STEM career*	*Aspiring* to *a non-STEM career*
"Science is that what attempts to describe everything based on evidence. The closest thing to truth we have" "A very broad category, which can lead to many different career opportunities. Overall, very interesting" "Find out about new development" "Very interesting but a job in research does not appeal to me"	"It's a way to understand and see the world from different perspectives" "It is an amazing aspect of life as we don't know the true value of it" "Amazing how everything is science" "It's pretty interesting as there are really clever scientists around"
"Studying it as AS level is much more interesting than GCSE" "I love science, it's by far the most interesting subject" "The more complicated, the more interesting"	"I find science interesting because you learn all about people and the world around you" "I find it interesting how all of the sciences can interlink with one another"
"Did have an interest, but the part of it that we were taught were so boring it killed that interest" "Not too good at it, doesn't interest me compared to rest" "I don't enjoy science and I do not understand it much"	"Didn't learn enough about the demand for it" "I don't know much about it" "Science is interesting but it's not something I am interested in"
"Good because of practicals and research" "Science experiments and research is very interesting" "The experiments are exciting when they produce results"	"Experiments are interesting" "Watching how good experiments turn out"

A Level students view towards Mathematics

Aspiring to *a STEM career*	*Aspiring* to *a non-STEM career*
"Maths is an universal language, I like that anyone can study it" "Fascinating because everything has maths behind it" "Need it for every other subject" "Required for certain jobs"	"Useful in everyday life" It is the national language of the world" Need it for all jobs" Interesting to know as Maths is involved and linked to many careers"
"I'm not too sure what a mathematician alone does but I know it can be used in a variety of fields" "I don't know how this could be transferred into a career" "Don't know much about careers in maths" "Highest thing you could do is teach maths if taken to degree level. It's essential for life"	"Don't really know what you could do with JUST a maths degree?" "I don't really know much about this in terms of careers"
"When applied, maths is an interesting subject" "I like how everything is derived from maths" "Puzzles always interested me"	"It's funny how we don't realise how the formulae we learn are going to be used in real life but when we do it's fascinating"
"I really enjoy it but I don't understand how it applies to anything" "Don't like maths much but am good at it"	"I know what's involved in maths but I don't find it very interesting" "Definitely difficult for me" "Knowing the basics is all you need"
"Simply enjoy the simplest of this subject as my family is mainly part of this field"	-

A Level students view towards Engineering

Aspiring to *a STEM career*	*Aspiring* to *a non-STEM career*
"Uses a mix of STEM attributes to make things. Very exciting for the future" "Engineering at its heart is problem solving, which is very satisfying" "It is interesting as it helps find new, innovative ways to do things" "It's just related to everything, nothing could be made without engineers" "Engineering brings the logic in maths to reality" "Buildings, infrastructure, technology, transport and more... We all owe this to innovative engineers"	"Blend of maths and physics which is logical education" "Engineering is developing so much, that fantastic concepts are being made" "Helps create new inventions"
"Useful, good job prospects"	-
"A very manly subject" "As a girl, I feel challenged to go down this route" "It seems dull" "I hear it's a choice between repairing roads and bridges, tars etc. to manufacturing things" "From what I know it's very practical and combines the subject of physics which I wouldn't like" "I understand it is a very complicated subject"	"I'm not sure what is learnt in engineering but I think it has something to do with building" "It comes in handy when fixing cars" "Have to be clever" "Interesting, dedicating, demandful in terms of skill"
"This is my favourite area since it is a combination of maths, science and design" "I am planning to go into engineering, because it is about applying the knowledge, which is more interesting" "I enjoy engineering and am considering a career in civil or mechanical engineering" "I'd like a career in this because I like hands-on work"	
"I know it's related to physics but I don't know much about it" "Not been taught much about it" "Would like to know more" "I don't know enough on the subject to comment on it"	"I don't know much about this, never been taught through school" "I know nothing about it" "Not very sure"
	"My dad does it so I know a lot about it" "I don't know much about it but my dad is an engineer"

A Level students view towards Computing/Technology

Aspiring to *a STEM career*	*Aspiring* to *a non-STEM career*
“Extremely interesting that technology is constantly improving. Everything depends on technology”	“I believe new developments are very important in our ever changing society”
“Useful for several careers”	
“Designing stuff on CAD is fun” “I've always been fascinated with computers and its development but most importantly software design” “I find programming intriguing”	“Highly interesting and very fun” “I am fascinated by technology”
“Coding is very fascinating. I wish I could learn it “This is something I want to learn more about as some of the things that can be done via computing are incredible” “I find this fascinating and wish more computer science was taught in school” “I don't really know much about this” “Not really interested, never done much of it”	“It seems complex” “I don’t know much about this”
	“Brother takes this”

Table 6.27: A level students’ views on science, mathematics, engineering and computing/technology

On the whole, Tables 6.26 and 6.27 detail a level of appreciation and awareness towards the relevance of the subjects and careers in STEM. This feedback also shows what aspects they enjoy, love, find interesting and outlines their understanding, lack of understanding, as well as areas that they find disengaging, boring and irrelevant. A rich representation of the image students associate with STEM subjects has been created through this feedback. Emphasis on the importance of developing a knowledgeable and informed view of STEM before the age of 15 has further been highlighted; thus, supporting the findings outlined by Archer (2013), who identified how young pupils form science related career aspirations between the ages of 10 and 14. It also appeared some students studying their GCSEs and A levels from this current study generally had a firm and fixed perception of STEM and were not interested to know more, though few demonstrated this; others although they were unaware were also curious to know more. This shows the level of difficulty present, especially if they are disengaged and disinterested, towards intriguing and inspiring students of this age into pursuing a career route in STEM.

6.5.6 GCSE, A level and STEM undergraduate students' recommendations to encourage more students studying STEM subjects at higher education

At the end of the survey, GCSE, A level and STEM undergraduate students were asked to make recommendations towards improving and increasing the pipeline of qualified STEM graduates. Attaining insights from GCSE and A level students that either were or were not engaged towards STEM, outlined approaches that they viewed could enhance and/or transform another student's outlook towards STEM. Whereas, suggestions by undergraduates that had chosen a higher education route within an area of STEM strengthened and corroborated an inclusive representation of how more students could be positively encouraged towards further study in STEM subjects.

Increasing the uptake of pre- and post-16 mathematics and science qualifications is an identified approach to support the uptake of STEM graduates (Broughton 2013), therefore, signifying the importance of gaining responses from these three academic groups of students. Their current stage of education allows them to reflect upon key strategies that if conveyed, according to their perception, can potentially contribute towards increasing another pupil's interest and aspiration of studying and pursuing a career in STEM. Below is an illustration demonstrating a collective view of GCSE, A level and STEM undergraduates about how this issue can be effectively addressed and how more students can be encouraged to study STEM subjects at higher education (see Figure 6.47).

Figure 6.47: An illustration outlining GCSE, A level and STEM undergraduate students' responses recommending approaches to increase the uptake of STEM undergraduates

An overall consensus was observed and agreement emerged from the student responses towards the importance of targeting pupils at a younger age. This view, strongly emphasised by all three groups of students, reinforces the importance of engaging young pupils into STEM prior to their decision-making process (Holman and Finegold 2010). Extracts from some of the remarks made by the students are listed below:

"To have more focus upon taster sessions and days at Years 7 and 8, before people fully decide their GCSEs. That way, young people will take science more seriously at an earlier stage for better future development".

GCSE student

"Encourage at a younger age e.g. primary school. When kids get to secondary school it's too late to persuade them to study sciences".

A level student

"Encouraging the teaching of practical application to students at a younger age. The theoretical aspects of engineering subjects are discouraging, it is their practical application that amazes students and encourages them".

STEM undergraduate student

Other STEM undergraduate students suggested that *"students' foundation years need to be strong"* and that we should *"engage at a lower age. Relevant teaching to younger pupils, make subjects cooler"* and another thoughtful comment was *"start in primary school, my personal experience was from my year 6 class"*.

These observations highlight the importance of interacting with students at an earlier age.

Great emphasis on engaging pupils through the element of fun was noted several times. A student studying A levels suggested the reason for doing this: *"at such a young age, children look for fun and excitement. It would be wrong to dump a lot of information of STEM on them. It would be best that we don't 'tell' them what STEM is. We 'show' them what it is - make it fun!"*

In this study, many students that participated in STEM outreach indicated that their experience could have been improved if it had included more elements that were fun (see Figure 6.39). For instance, suggestions respectively by A level and GCSE students were *"reach to them at a younger age, more fun schemes"* and take them on *"trips with hands-on, fun experiences that would be a useful insight for students"*.

Figure 6.46 shows how many students thought engagement in practical activities was an essential approach towards encouraging more pupils to be interested in STEM.

Student participants also shared a range of outreach activities as their key recommendation towards inspiring young pupils into STEM, including STEM days, hands-on experiences, trips, tasters, speakers (that were young and interesting) and projects. They detailed there should be *"more practical activities and talks and trips to* *explore the subject areas"* and that the young pupils should be shown *"the practical applications of each of them as it's a common train of thought that maths or science has no application in the real world"*. Further examples of specific outreach projects were provided. For instance, an A Level student suggested to *"offer more projects where students can work with companies on real problems (basically, like the Engineering Education Scheme) because that enables them to see what it would be like to work in that sector so they can know for themselves whether it's right for them"*, or not.

Another proposed approach was to *"give them more examples of the sort of jobs you can end up with. More projects like Bloodhound"*. This shows amongst the students a level of appreciation of engaging in STEM outreach was present and examples relating to various types of outreach activities were detailed as their key strategy for increasing the uptake of students studying STEM.

However, similar remarks were shown throughout the student responses' views on gaining access to STEM outreach and comments such as the below were made:

"Make STEM clubs at school more fun and open to all/available"
"Do more fun activities that are available for everyone"

GCSE students

"Make it more widely available, not just to high achieving pupils"
"More visits and presentations, more opportunities to ANYONE who has an interest even if they are not academically gifted"

A level students

"Wider outreach to less academic students as well. Be less sexist, many STEM projects were only open to women"

STEM undergraduate student

Macdonald (2014) expressed a concern towards pupils that are not part of the "elite" group, and this was especially towards those that are underrepresented and lack confidence in their ability to do STEM. They emphasise when “elite” students are selected for certain outreach activities it has the potential to negatively reinforce students’ perception towards considering that “STEM is not for them”. The views from this current study outline a similar message, as students used this opportunity to express dissatisfaction about the selection methods adopted for some outreach activities.

The results also detailed the need to provide a clearer link between the subjects and careers associated with STEM and that there should be *“more STEM days held at the school. Showing how STEM can benefit them when they leave school”*.

Some undergraduate students showed awareness of the gender imbalance that exists in STEM and commented that we need to *“get more girls, as they are the largest portion of people not interested in STEM”* and perhaps targeting *“outreach to all girls schools”* was a way forward, addressing the lack of underrepresentation of women in STEM.

The comments showed awareness and appreciation of the benefits that can arise through interacting with outreach activities and for many these were their key recommendation towards encouraging the uptake of young pupils in STEM. The great importance of targeting young pupils towards STEM subjects at an earlier age was outlined through techniques that reinforced elements of fun, interaction and practical based activities that can be provided through their STEM outreach experience.

These suggestions are a way of GCSE, A level and STEM undergraduate students expressing their views and ideas on future development. They have all experienced at least one key decision point and thus have recommended ways of encouraging more students to study science, technology, engineering and mathematics at higher education.

6.6 Key points from analysis of student data

The important messages emerging from this chapter are:

- Students remember STEM outreach events
- There is a strong association between participation in outreach and aspirations toward STEM (but causality not established)
- Still much work to be done amongst girls
- White students less likely than BME to aspire to STEM
- Knowledge of what computer science is, is very poor even amongst STEM undergraduates
- Need to stress wide range of STEM careers, do not all need degrees
- More fun and interaction is needed for all students
- More training for practitioners is needed to avoid long, boring talks
- Students have a lot to contribute, involving them in the dialogue is very beneficial

6.7 Summary

This chapter has presented an in-depth quantitative and qualitative analysis of the findings from the student data, and individually and collectively discussed the results provided by the three academic groups of students. As well as making relevant comparisons amongst the findings provided by the students from different gender and ethnicity, details on their participation in STEM outreach and its impact were presented and their key influences and decisions were discussed. A comprehensive overview of students' understanding in and awareness of STEM subjects and careers was further detailed, and this was followed by a descriptive summary of students' views to complement their overall perception of STEM. Students' strategies towards increasing the pipeline of qualified STEM graduates were also illustrated and key attributes were presented that were found to significantly affect the likelihood of a student aspiring to a career in STEM.

Chapter 7

Summary, Conclusions and Propositions

7.1 Introduction

This research has sought to examine the effectiveness of STEM outreach engagement and investigated approaches to enhance the delivery, impact and evaluation of STEM outreach from different perspectives. Key findings from Chapters 4, 5 and 6 are summarised and discussed, answering the four research questions presented in section 3.5. The practitioners and teachers, through semi-structured interviews, provided their outlook on factors that had the possibility of influencing the delivery and impact of STEM outreach. Similarly, the students, through questionnaires, provided an insight into factors that they felt enhanced their experience of STEM outreach. Based on the findings of this research, key conclusions and propositions are discussed.

Furthermore, to support the planning and delivery for future effective outreach activities, a prototype model is presented. By using this model the STEM community including practitioners, teachers, funders and policy makers will get a systematic overview of outreach and will enable them to better understand requiremnets of the end user (students). Finally, careful consideration is given towards future research and implications to further maximise the efficacy and impact of a students’ STEM outreach experience.

7.2 Summary of findings

The key findings from this research are detailed:

7.2.1 Key findings for research question 1

The key findings from the views of the practitioners are reported and summarised, answering RQ 1, set out in section 3.5:

RQ 1) What are practitioners' perspectives on student access and target year groups chosen for STEM outreach, the methodology of evaluation of outreach activities and its impact on students' views and understanding of STEM subjects?

Access to STEM Outreach

- Practitioners usually let the teachers decide which students are selected but sometimes impose criteria (e.g. number of spaces available, limitations set by funding source)
- Some practitioners consider all students should be provided access to outreach
- Generally the practitioners felt that the teachers are best placed to undertake the selection process
- There was some evidence of distrust of teachers judgement in selecting the suitable students for the activity
- Some practitioners showed signs of frustration towards gifted and talented schemes and instead preferred mixed ability student groups

Target year groups

- Choosing specific year groups to participate depended on the purpose and nature of the activity
- Outreach should be done earlier (in primary years) for raising the interest ("planting the seeds") of the students' but not later than year 7
- They highlighted that the "career focus" and to "support decision-making" outreach is important for year 10-11
- The practitioners expressed the views that the focus of outreach activities for year 12 should be "to retain"

Training for student helpers and volunteers

- There is great variation in the training provided to STEM practitioners
- There were practitioners who have developed extensive training programmes for their student helpers, to the extent that undergraduates can gain academic credit towards their degree by participating
- Secondly there are those practitioners who recognise that training is valuable but because of limited time and resource, end up offering training that they recognise as having limitations
- Finally there are those practitioners who offer little or no training initially and only introduce it to address identified failings in practice

Types of STEM Outreach activities

- Activities should be fun, interactive, simple and affordable

Practitioners' identified key interventions to support them in their role

- Practitioners require financial and administrative support so that they can do more activities
- Having an understanding of teaching practices is beneficial for someone involved with outreach
- It is important to maintain good relationships with teachers; dialogue before and after can lead to effective practice
- Teachers were seen as gatekeepers also barriers towards delivering effective STEM outreach

CPD for Teachers

- Practitioners generally believed STEM outreach activities can be an effective form of professional development for teachers and also saw these specific teacher CPD events as a good form of outreach

Evaluation Methodologies

- Qualitative feedback was preferred to quantitative feedback

- Dialogue with the students and teachers captured feedback more effectively than questionnaires
- Many practitioners are not rigorous in their approach to evaluation
- There is extensive variation in evaluation methodology with some being highly rigorous and some less rigorous

7.2.2 Key findings for research question 2

The key findings from the views of the teachers are reported and summarised, answering RQ 2:

RQ 2) What are teachers' perspectives on student access and target year groups chosen for STEM outreach, the methodology of evaluation of outreach activities and its impact on students' views and understanding of STEM subjects?

Access to STEM Outreach

- Often the selection process depended on student ability, although some teachers disagreed with this approach. Other factors were also considered such as commitment from students
- Teachers believed that sometimes universities seem only interested in high achievers, thereby side-lining many other interested students

Target year groups

- Choosing specific year groups to participate depended on the purpose of the activity
- Outreach for year 7-8 should have focus to "engage, enthuse and raise aspirations"
- They highlighted that the "career focus" and to "support decision-making" outreach is important for year 9-10
- The teachers expressed the views that the focus of outreach activities for year 12 should be "to retain"

Training for student helpers and volunteers

- Training must be provided for outreach practitioners and STEM ambassadors
- Teachers have mixed opinions about the quality of STEM practitioners. Some reporting that levels and styles of presentations can be pitched at wrong levels

Types of STEM Outreach activities

- Activities should be interactive, fun, engaging and stimulating
- Structured mini or long-term projects are preferred to single interventions
- Some teachers expressed that curriculum focused activities are more beneficial

Key factors influencing the degree of impact of STEM outreach

- Good pre-information is important as it can allow schools to prepare students appropriately
- Dialogue between the teachers and outreach practitioners is crucial before and after activities
- There is a need to ensure the activities are pitched appropriately
- STEM outreach is more likely to have a lasting impact if it is linked to the curriculum
- Quality outreach providers are highly likely to influence more students
- Teachers reported having experienced exceptionally inspiring events but also having encountered providers they would never use again. Teachers also expressed concerns that outreach could be a "lost opportunity" and could discourage students from STEM

Teachers' identified key interventions to support them in their role

- Teachers require time, administrative and financial support from schools
- Schools' ethos can support teachers' delivery of outreach
- Teachers believed that the outreach facilitator role had the potential to become a full-time post
- Teachers want recognition for their efforts, which are often voluntary

CPD for Teachers

- Teachers generally showed fewer signs than practitioners of believing that STEM outreach activities are an effective form of professional development
- Teachers want to be involved in the planning and delivery of outreach/part of outreach/partnership/than just organisation

Evaluation Methodologies

- Qualitative feedback was preferred to quantitative feedback
- Dialogue with the students captured feedback more effectively than questionnaires
- Some teachers were interested to see the feedback that had been collected by the outreach practitioners

7.2.3 Key findings for research question 3

The key findings from the views of the students are reported and summarised, answering RQ 3:

RQ 3) What are the students' perceptions of their understanding/lack of understanding of STEM subjects and careers? Is there a significant difference in the level of understanding of students who have participated in STEM outreach compared to other students?

Students understanding and enjoyment of STEM subjects and careers

- Reponses from GCSE students indicated the preference of enjoyment (high-low percentage) of subject; Biology, Mathematics, Design Technology, Chemistry and Physics
- Knowledge of what computer science is, is very poor amongst GCSE, A level and STEM undergraduates
- Many GCSE students had disconnected themselves from pursuing an engineering career despite not knowing what this was about

- Many GCSE and A level students said they want to know more about careers in computer science
- GCSE and A level students showed awareness of the importance of science and mathematics as subjects and careers

Differences in responses by STEM outreach participation

- GCSE students' self-reported understanding of what the subjects' mathematics, engineering, computer science, physics and chemistry are significantly improved
- A level students' self-reported understanding of what the subjects mathematics, engineering, physics, chemistry are significantly improved
- STEM undergraduate students' self-reported understanding of what the subjects engineering and computer science are significantly improved

Differences in responses by gender and ethnicity

- GCSE male students' self-reported understanding of what the subjects mathematics, physics, engineering and computer science are significantly better than GCSE female students
- A level male students' self-reported understanding of what the subjects mathematics, physics, engineering and computer science are significantly better than A level female students and the reverse was shown for understanding biology
- STEM undergraduate male students' self-reported understanding of what the subjects physics, engineering and computer science significantly better than STEM undergraduate female students
- There are significant differences in GCSE student responses on their understanding by ethnicity groups for the subjects mathematics, biology and chemistry
- There are significant differences in A level and STEM undergraduate student responses on their understanding by ethnicity groups for the subject physics

Types of STEM outreach activities

- There was a general consensus that activities should be interactive, fun and include practical elements
- The strength of this sentiment suggests that whilst practitioners also spoke of the importance of interactivity and fun, many activities perhaps do not have these characteristics to the level practitioners believe
- The student responses indicated that multiple interventions were more impactful

Selection of students and year groups chosen to participate in STEM outreach

- Students want an equal opportunity to participate in STEM outreach and do not agree with preference for academically high achievers and women
- STEM should be introduced to students prior to their decision-making process: the younger the student the higher the likelihood of influencing him/her towards studying STEM in higher education

7.2.4 Key findings for research question 4

The key findings on the views of GCSE and A level students' regarding their aspirations towards STEM careers are reported and summarised, answering RQ 4:

RQ 4) Is there a significant difference in students' aspirations for a STEM career amongst those who have participated in STEM outreach compared to other students?

Aspirations of a STEM career

- Similar proportions of GCSE students indicated that they aspire to pursue a career in STEM or they do not aspire a STEM career
- Most of the A level students indicated that they aspire to pursue a career in STEM

Differences in responses by STEM outreach participation

- The analysis showed that the higher the level of engagement in STEM outreach, the higher the likelihood of influencing GCSE and A level students' STEM career aspirations

Differences in responses by gender, ethnicity and obtaining careers advice

- The GCSE and A level female students were less likely to aspire to STEM careers than males
- Black GCSE and A level students were most likely to aspire to a career in STEM. The White students were the least likely to aspire to a STEM career
- GCSE and A level students who stated they received careers advice appeared to have increased likelihood of pursuing a career in STEM

7.3 Key conclusions and propositions

The key conclusions and propositions based on the findings of this research are detailed below.

7.3.1 Variability and quality

The data presented in this research has clearly indicated massive variability in practice in most areas related to STEM outreach. Including the training for student helpers and other volunteers (such as ambassadors from industry) and pitching at the wrong level. The research confirms this variability is not only of practice but also of quality. The concerns are that by allowing low quality outreach activities and unprepared practitioners to interact with students could potentially discourage more prospective STEM workforce. These bad experiences can stick with young people and could be a barrier in motivating and enhancing interest in STEM.

In order to address the above issues the following propositions are made:

- In order to ensure the quality of all the STEM outreach practices the need is that a STEM Outreach Quality Framework is developed.

- To enhance the quality of practice and engagement a training qualification for practitioners should be developed. This training should allow them to be “Certified STEM Outreach Practitioner”. It is important that the training should be enough to be effective but does not take too much time, as most of the practitioners are giving time voluntarily.

- The STEM community should effectively share practice in order to learn from each other’s experiences. A STEM outreach community online platform could be helpful in sharing practice effectively.

7.3.2 Interaction between practitioners, teachers and students

The data presented in this research has indicated a mismatch of mind-set between the teachers and practitioners at all levels of outreach practice. Practitioners seem to follow provider-recipient model whilst teachers prefer a partnership approach.

The lack of understanding and distrust among both parties is also evident. Furthermore, the need of close partnership, dialogue before and after the activity, understanding the engagement and learning needs of the students is also highlighted.

In order to address the above issues the following propositions are made:

- For outreach to be as effective as possible there should be good communication between all the stakeholders. Dialogue between students, teachers and practitioners is extremely important to understand each other’s expectations and needs.

- Effective communication is needed at all stages, before the event takes place (e.g. to discuss student selection, topics to be covered); during the event (e.g. to address levels of pitching) and after the event (particularly for evaluation).

- A close working relationship may be ideal to overcome the indicated tensions and suspicions. As these may have a tendency to limit communication and can therefore create a vicious circle of less communication.

7.3.3 School/College STEM ethos

Both practitioners and teachers have indicated that for effective outreach they require more financial and administrative support. In addition to this the teachers indicated that they require more time, structural support and recognition of efforts.

Another important point, which was highlighted in the research, was that not all students are given access to outreach. This is not in line with equal opportunity practice. This is due to financial constraints and criteria set up by the funding bodies.
As a result we might be missing on targeting the students who could be a part of the future STEM workforce.

In order to address the above issues the following propositions are made:

- The need is that schools/colleges should value and support the teachers in their efforts.

- Teachers involved in outreach should be provided time, financial and administrative support.

- Most importantly the STEM community should provide access to sustained outreach to every student of all ages during compulsory education. The need is that such outreach activities should be created which are cost-effective and could be available for all students. For this purpose, the use of learning technologies, media and new pedagogies should be explored.

7.3.4 Type of activity

The data presented in this research has indicated that it is preferred that the outreach activities are targeted according to the learning needs of the age group. For end primary/early secondary years more engaging and aspiration raising type activities are preferred. The practitioners and teachers report that career focused and activities supporting in decision-making are preferred for GCSE students. These students are at an important phase of their academic career as they will be thinking about making A level choices. While for A level students, activities which could keep them motivated to take up a STEM career are preferred. Furthermore, the findings have also indicated that the teachers are more in favour of curriculum focused activities.

In comparison, the students of all ages have preferred more fun, engaging, career focussed and interactive activities. Students also prefer multiple interventions.

In order to address the above points the following proposition is made:

- Effective dialogue, communication and partnership between all stakeholders are required throughout the outreach experience.

7.3.5 Evaluation methodologies

The research highlighted great variation in evaluation practices undertaken by practitioners. Few practitioners were very rigorous in their approach to evaluation and carried out longitudinal studies. Others were not so rigorous and just did an exercise to satisfy their funding requirements.

Qualitative feedback was preferred over quantifiable approaches, as it provided more understanding of students learning. Teachers indicated that more effective feedback could be captured by dialogue with students.

In order to address the above issues the following propositions are made:

- Dialogue with the teachers is essential after the outreach activity. Communication after the event can provide valuable feedback to practitioners and also help teachers to build on enthusiasm generated by the outreach event.

- Effective sharing of practice between the STEM outreach practitioners is required to improve the evaluation methodologies and delivery.

- The STEM outreach community should develop a generic evaluation tool to capture evidence that is rigorous and meaningful. This should be freely available to all STEM practitioners.
  This evaluation tool should be based on social science research methodologies. This will enhance the learning of the practitioners in order to deliver effective outreach.

7.3.6 Limitations and challenges to the STEM community to achieve best practice

Developing training programmes through which practitioners have the opportunity to become a "Certified STEM Outreach Practitioner" may encounter difficulties. A key reason for this could be variability; as every subject area is different and every individual involved in this process is different too. Thus, for this training programme to result in quality outcomes, the needs of specific individuals must be met efficiently. Another factor that can impact the development could be lack of funding opportunities, limiting the amount of time and resources spent towards creating such effective training programmes. Nevertheless, it is possible that this training programme is linked to the existing STEM Ambassador title but with a formal training requirement, though it may be difficult to ensure all practitioners engage with this unless it has a mandatory requisition from a regulatory body.

Furthermore, encouraging practitioners to utilise an online platform to share good practice may be challenging, as some may not find themselves comfortable to follow such culture. Thus following this trend may be problematic for some individuals, especially for those who are not competent with technology. In addition, STEM practitioners have a different approach and do not follow set criteria whilst designing and preparing for their outreach activity. Sharing a complex procedure online could result in inconsistent outputs. Although there are potential complications to ensuring an online platform is used, resources such as workshops and videos could possibly be designed that demonstrate the process and benefits of continuously sharing good practice online.

Another area that may cause difficulties is achieving a close working relationship between teachers and STEM practitioners. They are both under increasing pressure in their daily workloads and generally have high levels of commitment with dual priorities. Additionally their involvement in outreach is often voluntary, so their support relies on goodwill and this can often be challenging as shown in this current study. Thus, it is important teachers and STEM practitioners are recognised for their efforts and are given some designated time to closely work together and understand each other's expectations in a formal environment. This will further support the development of a STEM community that aims to maintain best practice (Bell 2013).

As shown in this current study, not all schools/colleges value and support a STEM ethos and give recognition to the valuable work put in my teachers, and instead are focusing on other strands such as their performance in league tables and their school reputation. This therefore makes it difficult for teachers to conduct quality STEM outreach activities. Thus, it is important that as a STEM community we sustain an environment where schools give prominence to STEM and support the efforts put forward by teachers to achieve a "sustainable and coordinated approach to STEM outreach" (Packard 2011).

7.3.7 Proposed model of the STEM outreach system

Based on this analysis, a proposed model of the complete STEM outreach system is illustrated in Figure 7.1 (which is developed from Figure 3.1) to support the attainment of the maximum effect from the process of delivery and impact of STEM outreach. Figure 7.1 displays how modifications can be incorporated to enhance the message that is sent and received between those involved in STEM outreach.

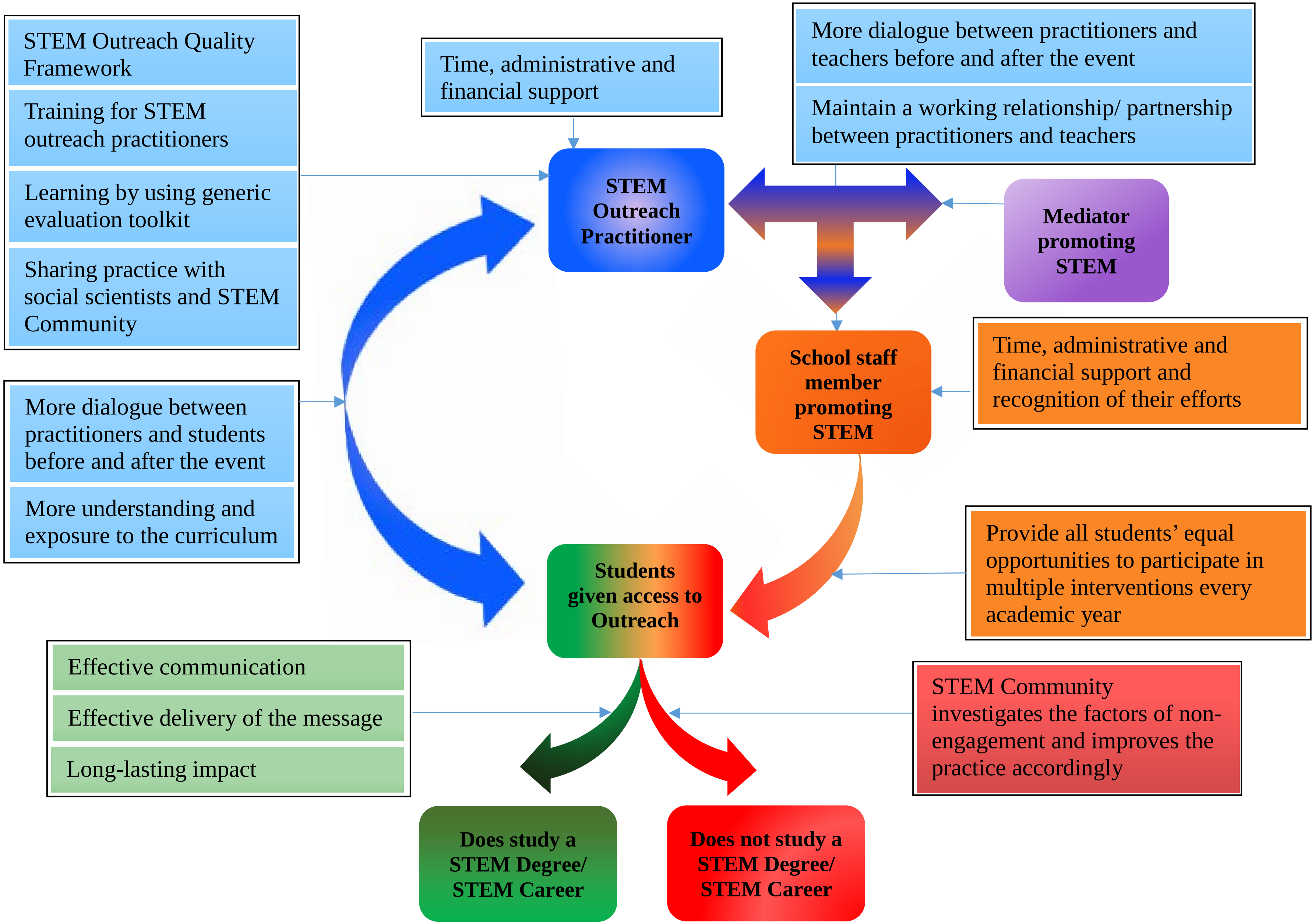

Figure 7.1: Proposed STEM Outreach Model

7.4 Future research

This current research, through a mixed methods approach, did a systematic overview and examined the relationship between the key stakeholders involved in STEM outreach and proposed a prototype model to enhance the engagement and delivery of STEM outreach.

The key areas of further research identified are; development of a portfolio of STEM outreach activities, development of STEM outreach Quality Framework, development of an effective training qualification for STEM outreach practitioners and development of a generic evaluation toolkit.

This research has shown that repeated exposure to STEM outreach is more effective than one-off interaction. However, to supply all students with access to repeated STEM outreach activities is a massive undertaking. In order to facilitate this development and sharing of ‘off the shelf’, easy to deliver, activities should be investigated. The potential of online delivery could also be explored as a cost-effective way of providing stimulating outreach activities to a wider group of students.

The other proposition of this research is the design of a generic evaluation toolkit that can be freely accessed by everyone in the STEM community. Through this, a coordinated national approach can be implemented, capturing effective and meaningful feedback on all type of STEM outreach activities.

Another important area of future research identified is development of Quality Assurance procedures for STEM outreach. This includes the development of STEM Outreach Quality Framework and effective training for STEM outreach practitioners. The STEM Outreach Framework should act as a quality guide for practitioners in providing outreach. Such a Framework should cover the whole outreach system, not just the development of the actual activity. The latter has the focus of quite a lot of attention but the ‘bits around the edges’ (e.g. Interaction with teachers, linking with the curriculum, training, and evaluation) have received much less attention.

7.5 Summary

The research undertaken provides a systematic overview of relationships between all stakeholders in STEM outreach. The research explored the views of the practitioners and teachers before the activity, including selection process, organisation and planning. It also explored the quality, delivery and impact of the activity. Further the views of the students at three transitional educational stages were captured on different types of outreach activities and their impact. A prototype STEM outreach model is also presented based on the findings, which will be very useful for the STEM community in order to improve the practice and gain a better understanding of the system.

This is an extremely useful, relevant, and important research for the STEM community. To the best of my knowledge and, as suggested by the literature review, no similar study has been undertaken. All the previous research undertaken focused on one or two aspects of STEM outreach but not the complete overview. Finally, future work has been outlined based on the findings of this research.

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Appendices

Appendix A: Interview questions for STEM Practitioners

1. Please tell me some background information about yourself.
- What is your education background?
- Why are you interested in outreach?
- Do you believe outreach is important and useful, why? What do you consider is your main aim of facilitating such outreach programme?
- What are your views on making outreach compulsory for students to take part in as part of the national school curriculum?

2. Please provide a brief description on the type of outreach work you carry out?
- What subjects are your outreach programs targeted to?
- What age group are your outreach programs targeted to?
- If more than 1, then at what age did you find the outreach programs to be most effective and why? Least effective and why?

3. Are you thinking about target groups when deciding activities?
- What do you feel are the factors which are affecting the impact of the activities when targeting women and minorities that are underrepresented in STEM?
- How can this be improved?
- When designing this, what factors do you consider so you can influence all students and especially encourage the women and minorities?

4. How do you design these activities?
- When designing the outreach programs, do you consider age group?
- When designing the outreach programs, do you consider the student's ability set?
- Do the outreach programs accommodate for different learning styles? If yes how?
- Is it possible to link outreach programs to the existing curriculum?
- When designing the outreach programs, did you think where it will line with the curriculum?
- To what extent is a teacher at school involved in designing these activities? Who selects the students for your outreach- any specific criteria?
- Do you feel the teachers are trained with respect to knowledge and understanding of STEM subjects?

5. What is the pedagogy behind this?
- What goes behind creating/developing/designing/planning these outreach programs?
- Why did you design them in a particular way?
- How do you judge whether your aim was successful? Aim- motivate, encourage, engage etc.
- What measures are you taking into account when deciding it has worked or not worked?
- How do you measure if engagement, learning etc. is taking place?
- What are your evaluation methodologies?
    - Who do you collect feedback from? Students, teachers, parents?
    - How do you collect feedback? Are they one off feedbacks or longitudinal feedbacks?
    - How do you incorporate the evaluation of the activities in improving future outreach work?

6. Do you have any suggestions for evaluation process and delivery?

Appendix B: Interview questions for Teachers

1. Please tell me some background information about yourself.
- What is your education background?
- What age group do you teach? What subject do you specialise in?
- What are your views on outreach?
- Do you believe outreach is important, useful and valuable, why?
- What are your views on making outreach compulsory for students to take part in as part of the national school curriculum?

2. To what extents are you involved in designing these outreach activities? Would you like to give in more input?
- Do you feel you have enough up-to-date information with respect to knowledge and understanding of STEM subjects and how they all integrate with each other?
- Is there enough information and training given to you to share with the students about the importance of STEM or would you like more? How do you access this information?
- Do the outreach programs accommodate for different learning styles? If yes/no, how?
- Do you feel outreach programs are in line with the curriculum? How can this be improved?
- Is it possible to link outreach programs to the existing curriculum?

3. How does the selection process take place? What factors do you consider when selecting students for outreach programs? How do you make it accessible to all students?
- How are the students selected on which outreach activity they do? Who decides?
- Are you thinking about target groups when deciding activities?
- What do you feel is going wrong when targeting women and minorities that are underrepresented in STEM? How can this be improved?
- During the selection process, what factors do you consider so you can influence all students and especially encourage the women and minorities to take part in outreach?

4. Please provide a brief description on the type of outreach work you've previously been involved in.
- What subjects were the outreach programs targeted to?
- What age group were the outreach programs targeted to?
- If more than 1, then at what age did you find the outreach programs to be most effective and why? Least effective and why? Describe effective? Eg Science if fab?
- Overall, which type of outreach activity did you find most effective towards students? Why? Least effective and why?

5. What measures are you taking into account when deciding it has been effective/informative/influential or when it has not worked and shown no impact and kept students attitude towards STEM the same?
- How do you measure if engagement, learning etc. has taken place?
- Do you have any suggestions for evaluation process and delivery?
    -What are your evaluation methodologies?
    - Who do you collect feedback from? Students, parents, practitioners?
    - How do you collect feedback? Are they one off feedbacks or longitudinal feedbacks?

6. Do you consider yourself being their teacher, to have an influential factor on students deciding what career path they should take?

Appendix C: Project information and participant consent form for STEM Practitioners, Teachers, GCSE, A level and first year STEM undergraduate students

Project Information

I am currently a PhD student at Coventry University, looking into the area of mathematics education that involves a detailed analysis of a number of Science, Technology, Engineering and Mathematics (STEM) outreach projects. STEM outreach activities are seen as an enrichment and enhancement (E&E) STEM activity undertaken by students whilst at school. Several outreach projects have been designed to give motivation and interest in STEM subjects and so encourage more students to take up STEM related courses at University and so as a profession. For my project I will study whether STEM outreach has influenced your decision to take up a STEM related degree or not and why.

Participation in this study is entirely voluntary. All information collected about individuals will be kept strictly confidential and the data collected will be used for educational research purpose only and no individual students will be reported after.

To participate in the research, please read the following statement and sign below.

Participant Consent

I agree to take part in the Coventry University research project specified above. The project has been explained to me, I have read the above statement and I understand that by signing below:

- I agree to complete the questionnaire.
- I consent to the use of the information I provide for the research.
- I understand that my participation is voluntary, that I can choose not to participate in part or all of the project, and that I can withdraw at any stage of the project without being penalised or disadvantaged in any way.
- I understand that any data that the researcher extracts from the questionnaire for use in reports or published findings will not, under any circumstances, contain names or identifying characteristics.

Name: ______________________________________

Signature: ______________________________________

Date: ______________________________________

I'm willing to be contacted again for a follow up on my responses to this questionnaire:

Yes ☐ No ☐

*If ticked **Yes**, please provide an email address:*

____

Thank you very much for helping with this research.

Yamuna Bagiya

Appendix D: Questionnaire for GCSE Students

This *questionnaire will collect information on extra-curricular activities for students studying their GCSEs.*

1. a) Name of School/College: ______________________ b) Gender: Male Female ☐
2. a) Ethnicity: ***Please check on the last page for ethnicity code*** b) UK National: Yes No
3. Household Income: **(Tick one only)** £10,000 - £20,000 ☐ £20,000 - £30,000 ☐ Over 30,000
4. Are you entitled to Free School Meals? Yes ☐ No ☐
5. Has one or more of your parent(s)/guardian(s) completed a University degree? Yes ☐ No ☐
6. Please provide the first 3 characters of your postcode: ________________ ***(For example CV1)***
7. List the GCSE **subjects** you are currently studying **and** note the **grade** you have been predicted for each subject in the box provided:
8.

1. ________________ ☐	5. ________________ ☐	9. ________________ ☐
2. ________________ ☐	6. ________________ ☐	10. ________________ ☐
3. ________________ ☐	7. ________________ ☐	11. ________________ ☐
4. ________________ ☐	8. ________________ ☐	12. ________________ ☐

9. Which subjects do you enjoy/find interesting? **(Tick all that apply)**
   Mathematics ☐ Chemistry ☐ Biology ☐ Physic ☐ Environmental Science ☐ Astronomy ☐
   Electronics ☐ Design and Technology ☐ ICT ☐ Computing ☐ Engineering ☐ None ☐

10. After finishing your GCSEs, what are you planning to do next? **(Tick one only)**
    A levels ☐ BTEC course ☐ Diploma ☐
    Applied A levels ☐ NVQ course ☐ International Baccalaureate Diploma ☐
    Apprenticeship ☐ Traineeship ☐ Not sure yet ☐
    Part-time education or training whilst working/volunteering ☐ Other *(please specify)* _________

11. At what academic stage did you become sure about what you wanted to do after finishing your GCSEs? (Tick **one only)**

    Before Year 6 (Primary) ☐ Year 7-9 (Lower secondary) ☐
    Year 10-11 (GCSEs) ☐ Still not sure ☐

12. Who or what do you see as the major influence on your course choice? **(Tick one only)**

Parents ☐	Family Members ☐	Interest/Enjoyment of Subject ☐
Teachers ☐	You're good at it ☐	Extra-Curricular Activities ☐
Friends ☐	Personal Choice ☐	Still not sure ☐
Career Fairs ☐	Work Experience ☐	Other *(please specify)* ________________ ☐

13. Are you thinking of having a career which is Science, Technology, Engineering and/or Mathematics related?

    Yes ☐ No ☐ *If you know what you want to be please share:* ______________________

14. Did an internal or external adviser visit your school or did you visit an institution to help you understand the available options following your GCSEs?

    Yes ☐ No ☐

    If Yes, which **School Year(s)** did this happen in? _____________

15. At school, have you taken part in **extra-curricular** Science, Technology, Engineering and Mathematics (STEM) activities? **(See Question 19 for a list of examples of STEM activities- If unsure please ask)**

    Yes ☐ No ☐ ***If No, please go to Question 28***

    If Yes, which **School Year(s)** did this happen in? _____________

16. Number of sessions you attended *(estimate)*: 1 session ☐ 2-5 sessions ☐ 6-10 sessions ☐ 10+ sessions ☐

17. On average, how long were the activities? **(Tick <u>one</u> only)**

    1 hour ☐ 2 hours ☐ Half a day ☐ 1 day ☐ More than 1 day ☐

    Please give brief details of what you did in the activities:

    ____

    ____

18. Which subject(s) were the activities related to? **(Tick <u>all</u> that apply)**

    Science ☐ Technology ☐ Engineering ☐ Mathematics ☐

19. What type of STEM activities did you do? **(Tick <u>all</u> that apply)**

STEM days ☐	STEM Ambassadors events ☐	Master classes/lectures ☐
Competitions ☐	Attended seminars ☐	Undergraduate shadowing ☐
Taster courses ☐	Mentoring schemes ☐	Hands on interactive placement ☐
Careers academy ☐	Summer placement ☐	Other *(please specify)* ____________ ☐

20. If you've done more than one, which activity did you enjoy **most** from those that you ticked in Question 19? **(Tick <u>one</u> only) – *If only done one type of activity, please go to question 22***

STEM days ☐	STEM Ambassadors events ☐	Master classes/lectures ☐
Competitions ☐	Attended seminars ☐	Undergraduate shadowing ☐
Taster courses ☐	Mentoring schemes ☐	Hands on interactive placement ☐
Careers academy ☐	Summer placement ☐	Other *(please specify)* ____________ ☐

21. If you've done more than one, which activity did you enjoy **least** from those that you ticked in Question 19? **(Tick <u>one</u> only) – *If only done one type of activity, please go to question 22***

STEM days	☐	STEM Ambassadors events	☐	Master classes/lectures	☐
Competitions	☐	Attended seminars	☐	Undergraduate shadowing	☐
Taster courses	☐	Mentoring schemes	☐	Hands on interactive placement	☐
Careers academy	☐	Summer placement	☐	Other *(please specify)* ________	☐

22. How interesting were the activities? **(Tick <u>one</u> only)**

Very Interesting ☐ Ok ☐ Boring ☐

23. Overall, did you enjoy the activities? **(Tick <u>one</u> only)**

Not at all ☐ A little ☐ Quite a bit ☐ Very much ☐

24. How much awareness and knowledge did you gain about STEM related subjects? **(Tick <u>one</u> only)**

Not at all ☐ A little ☐ Quite a bit ☐ Very much ☐

25. How much influence did this make towards your decision of further studying STEM related subjects after completing your A levels? **(Tick <u>one</u> only)**

Not at all ☐ A little ☐ Quite a bit ☐ Very much ☐

26. Due to taking part in STEM activities, are you more likely to consider a career in STEM than you might have before? **(Tick <u>one</u> only)**

Not at all ☐ A little ☐ Quite a bit ☐ Very much ☐

27. How could the activities have been improved? **(Tick <u>all</u> that apply)**

More interaction	☐
Better organisation	☐
Made it more fun	☐
Having enthusiast and engaging STEM practitioners	☐
Providing more information about STEM subjects	☐
Providing more information about STEM degrees	☐
Providing more information about STEM careers	☐
Providing more information about how STEM relates to real world	☐
Other *(please specify)* ________	☐

28. As a whole, how much do you understand about the following subjects? *Please be honest* **(Tick <u>one</u> response for each subject)**

Subject	**Not at all**	**A little**	**Quite well**	**Very well**
Engineering				
Computer Science				
Mathematics				
Physics				
Chemistry				
Biology				

29. In what academic year did you clearly understand what the following professions actually do? *Please be honest* **(Tick <u>one</u> response for each profession)**

Professional areas	Before Year 6 (Primary)	Year 7-9 (Lower Secondary)	Year 10-11 (GCSEs)	Still don't know
Engineers				
Computer Scientist				
Mathematicians				
Physicist				
Chemist				
Biologist				

30. In few words can you express your opinion on the following areas: ***(For example, Engineering: It's fascinating when you discover how something works due to the maths and science behind it OR It's not very interesting OR I don't really know much about it OR I love a challenge and this is exactly it!)***

Science:

Computing/Technology:

Engineering:

Maths:

31. If you have any ideas of how we could encourage more young students to apply to study Science, Technology, Engineering and Mathematics (STEM) subjects at university then please provide details below:

<u>Ethnicity</u> - For **Question 2a)** please choose a **code** that best describes your ethnic group or background and **write** it in the box provided on the **first** page.

Code	**Ethnicity**
	White
1	English/ Welsh/ Scottish/ Northern Irish/ British
2	Irish
3	Gypsy or Irish Traveller
4	Any other White background
	Mixed/ Multiple ethnic groups
5	White and Black Caribbean
6	White and Black African
7	White and Asian
8	Any other Mixed/ Multiple ethnic background
	Asian/ Asian British
9	Indian
10	Pakistani
11	Bangladeshi
12	Chinese
13	Any other Asian background
	Black/ African/ Caribbean/ Black British
14	African
15	Caribbean
16	Any other black/African/ Caribbean background
	Other ethnic group
17	Arab
18	Any other ethnic group

Thank you for completing this questionnaire.

Appendix E: Questionnaire for A level Students

This questionnaire will collect information on extra-curricular activities for students studying their A levels.

1. a) Name of School/College: ___________________________ b) Gender: Male ☐ Female ☐
2. a) Ethnicity: ☐ ***Please check on the last page for ethnicity code*** b) UK National: Yes ☐ No ☐

3. Household Income: **(Tick <u>one</u> only)** £10,000 - £20,000 ☐ £20,000 - £30,000 ☐ Over £30,000 ☐
4. Are you entitled to Free School Meals? Yes ☐ No ☐
5. Has one or more of your parent(s)/guardian(s) completed a University degree? Yes ☐ No ☐

6. Please provide the first 3 characters of your postcode: _______________ ***(For example CV1)***
7. List the **AS level subjects** you have studied **and** note the **grade** you have been predicted/obtained for each subject in the box provided: ***If you're in Year 12, please go to question 9***
8.

1. __________________ ☐ 2.__________________ ☐ 3. ________________ ☐

3. __________________ ☐ 5.__________________ ☐

9. List the **A2 level subjects** you are currently studying **and** note the **grade** you have been predicted for each subject in the box provided:
10.

1. __________________ ☐ 2.__________________ ☐ 3. ________________ ☐

3. __________________ ☐ 5.__________________ ☐

11. After finishing your A levels, what are you planning to do next? **(Tick <u>one</u> only)**

Going to University	☐	Working for a company and gaining a Degree/Professional Qualification	☐
Apprenticeship	☐		
Taking a Gap Year	☐		
Studying Overseas	☐	Working (without further education)	☐
Not sure yet	☐	Other *(please specify)* ____________________	☐

12. At what academic stage did you become sure about what you want to do after finishing your A levels? **(Tick <u>one</u> only)**

Before Year 6 (Primary)	☐	Year 7-9 (Lower secondary)	☐	Year 10-11 (GCSEs)	☐
Year 12-13 (A levels)	☐	Still not sure	☐		

13. Who or what do you see as the major influence on your course choice? **(Tick <u>one</u> only)**

Parents	☐	Family Members	☐	Interest/Enjoyment of Subject	☐
Teachers	☐	You're good at it	☐	Extra-Curricular Activities	☐
Friends	☐	Personal Choice	☐	Still not sure	☐
Career Fairs	☐	Work Experience	☐	Other *(please specify)* __________________	☐

14. Are you thinking of having a career which is Science, Technology, Engineering and/or Mathematics related?

    Yes ☐ No ☐ *If you know what you want to be please share:* ______________________

15. How sure are you about the career you want to pursue after finishing your A levels? **(Tick <u>one</u> only**

    Very sure ☐ Quite sure ☐ Neither sure nor unsure ☐ Quite unsure ☐ Very unsure ☐

16. Did an internal or external adviser visit your school or did you visit an institution to help you understand the available options following your A levels?
    Yes ☐ No ☐

    If Yes, which **School Year(s)** did this happen in? _____________

17. At school, have you taken part in **extra-curricular** Science, Technology, Engineering and Mathematics (STEM) activities? **(See Question 19 for a list of examples of STEM activities- If unsure please ask)**

    Yes ☐ No ☐ ***If No, please go to Question 28***

    If Yes, which **School Year(s)** did this happen in? _____________

18. Number of sessions attended *(estimate:)* 1 session ☐ 2-5 sessions ☐ 6-10 sessions ☐ 10+ sessions ☐

19. On average, how long were the activities? **(Tick <u>one</u> only)**

    1 hour ☐ 2 hours ☐ Half a day ☐ 1 day ☐ More than 1 day ☐

    Please give brief details of what you did in the activities:

    ____

    ____

20. Which subject(s) were the activities related to? **(Tick <u>all</u> that apply)**

    Science ☐ Technology ☐ Engineering ☐ Mathematics ☐

21. What type of STEM activities did you do? **(Tick <u>all</u> that apply)**

STEM days ☐	STEM Ambassadors events ☐	Master classes/lectures ☐
Competitions ☐	Attended seminars ☐	Undergraduate shadowing ☐
Taster courses ☐	Mentoring schemes ☐	Hands on interactive placement ☐
Careers academy ☐	Summer placement ☐	Other *(please specify)* ______________ ☐

22. If you've done more than one, which activity did you enjoy **most** from those that you ticked in Question 19? **(Tick <u>one</u> only) –** ***If only done one type of activity, please go to question 22***

STEM days ☐	STEM Ambassadors events ☐	Master classes/lectures ☐
Competitions ☐	Attended seminars ☐	Undergraduate shadowing ☐
Taster courses ☐	Mentoring schemes ☐	Hands on interactive placement ☐
Careers academy ☐	Summer placement ☐	Other *(please specify)* ______________ ☐

23. If you've done more than one, which activity did you enjoy **least** from those that you ticked in Question 19? **(Tick <u>one</u> only) –** ***If only done one type of activity, please go to question 22***

STEM days	☐	STEM Ambassadors events	☐	Master classes/lectures	☐
Competitions	☐	Attended seminars	☐	Undergraduate shadowing	☐
Taster courses	☐	Mentoring schemes	☐	Hands on interactive placement	☐
Careers academy	☐	Summer placement	☐	Other *(please specify)* ______________	☐

24. How interesting were the activities? **(Tick <u>one</u> only)** Very interesting ☐ Ok☐ Boring☐

25. Overall, did you enjoy the activities? **(Tick <u>one</u> only)**

Not at all ☐ A little ☐ Quite a bit ☐ Very much ☐

26. How much awareness and knowledge did you gain about STEM related subjects? **(Tick <u>one</u> only)**

Not at all ☐ A little ☐ Quite a bit ☐ Very much ☐

27. How much influence did this make towards your decision of further studying STEM related subjects after completing your A levels? **(Tick <u>one</u> only)**

Not at all ☐ A little ☐ Quite a bit ☐ Very much ☐

28. Due to taking part in STEM activities, are you more likely to consider a career in STEM than you might have before? **(Tick <u>one</u> only)**

Not at all ☐ A little ☐ Quite a bit ☐ Very much ☐

29. How could the activities have been improved? **(Tick <u>all</u> that apply)**

More interaction	☐
Better organisation	☐
Made it more fun	☐
Having enthusiast and engaging STEM practitioners	☐
Providing more information about STEM subjects	☐
Providing more information about STEM degrees	☐
Providing more information about STEM careers	☐
Providing more information about how STEM relates to real world	☐
Other *(please specify)* ______________________________	☐

30. As a whole, how much do you understand about the following subjects? *Please be honest* **(Tick <u>one</u> response for each subject)**

Subject	**Not at all**	**A little**	**Quite well**	**Very well**
Engineering				
Computer Science				
Mathematics				
Physics				
Chemistry				
Biology				

31. In what academic year did you clearly understand what the following professions actually do? *Please be honest* **(Tick <u>one</u> response for each profession)**

Professional areas	**Before Year 6 (Primary)**	**Year 7-9 (Lower Secondary)**	**Year 10-11 (GCSEs)**	**Still don't know**
Engineers				
Computer Scientist				
Mathematicians				
Physicist				
Chemist				
Biologist				

32. In few words can you express your opinion on the following areas: ***(For example, Engineering: It's fascinating when you discover how something works due to the maths and science behind it OR It's not very interesting OR I don't really know much about it OR I love a challenge and this is exactly it!)***

Science:	Computing/Technology:
Engineering:	Maths:

33. If you have any ideas of how we could encourage more young students to apply to study Science, Technology, Engineering and Mathematics (STEM) subjects at university then please provide details below:

<u>Ethnicity</u> –For **Question 2a)** please choose a **code** that best describes your ethnic group or background and **write** it in the box provided on the **first page**.

Code	**Ethnicity**
	White
1	English/ Welsh/ Scottish/ Northern Irish/ British
2	Irish
3	Gypsy or Irish Traveller
4	Any other White background
	Mixed/ Multiple ethnic groups
5	White and Black Caribbean
6	White and Black African
7	White and Asian
8	Any other Mixed/ Multiple ethnic background
	Asian/ Asian British
9	Indian
10	Pakistani
11	Bangladeshi
12	Chinese
13	Any other Asian background
	Black/ African/ Caribbean/ Black British
14	African
15	Caribbean
16	Any other black/African/ Caribbean background
	Other ethnic group
17	Arab
18	Any other ethnic group

Thank you for completing this questionnaire.

Appendix F: Questionnaire for First year STEM Undergraduate Students

This questionnaire will collect information on extra-curricular activities for students studying STEM related degrees.

1. a) Gender: Male ☐ Female ☐ b) UK National: Yes ☐ No ☐

2. Ethnicity: ☐ ***Please check on the last page for ethnicity code***

3. Programme or Degree Title: ______________________________

4. What recent qualification do you have? **(Tick __one__ only)**

   A levels ☐ Vocational course ☐ International Baccalaureate ☐
   Overseas ☐ National Diploma ☐ Foundation degree ☐
   BTEC ☐ Other *(please specify)* ☐ _________________________

   If Overseas, which country did you undertake your pre-University Education?
   ____

5. Before course selection, were you aware of what you want to do as a career after finishing University?

   Yes ☐ No ☐

6. When choosing which course you wanted to study at University, how sure were you about the career you want to pursue after University? **(Tick __one__ only)**

   Very sure ☐ Quite sure ☐ Neither sure nor unsure ☐ Quite unsure ☐ Very unsure ☐

7. What do you see as the primary influence on your course choice? **(Tick __one__ only)**

   Parents ☐ Family Members ☐ Interest/Enjoyment of Subject ☐
   Teachers ☐ You're good at it ☐ Extra-Curricular Activities ☐
   Friends ☐ Personal Choice ☐ Other *(please specify)* _____________ ☐
   Career Fairs ☐ Work Experience ☐

8. At what academic stage did you become sure about the course you wanted to study at University? **(Tick __one__ only)**

   Before Year 6 (Primary) ☐ Year 7-9 (Lower secondary) ☐
   Year 10-11 (GCSE) ☐ Year 12-13 (A levels) ☐

   If you are a mature student, please specify at which age this happen in: __________

9. Did an internal or external adviser visit your school or did you visit an institution to help influence your career choice?

   Yes ☐ No ☐

   If Yes, which **School Year(s)** did this happen in? ______________

10. At school, have you taken part in **extra-curricular** Science, Technology, Engineering and Mathematics **(STEM)** activities? **(See Question 14 for a list of examples of STEM activities- If unsure please ask)**

    Yes ☐ No ☐ ***If No, please go to Question 21***

    If Yes, which **School Year(s)** did this happen in? _______________

11. Number of sessions attended *(estimate):* 1 session☐ 2-5 sessions☐ 6-10 sessions☐ 10+ sessions ☐

12. On average, how long were the activities? **(Tick <u>one</u> only)**

    1 hour ☐ 2 hours ☐ Half a day ☐ 1 day ☐ More than 1 day ☐

    Please give brief details of what you did in the activities:

    ____

    ____

13. Which subject(s) were the activities related to? **(Tick <u>all</u> that apply)**

    Science ☐ Technology ☐ Engineering ☐ Mathematics ☐

14. What type of STEM activities did you do? **(Tick <u>all</u> that apply)**

STEM days	☐	STEM Ambassadors events	☐	Master classes/lectures	☐
Competitions	☐	Attended seminars	☐	Undergraduate shadowing	☐
Taster courses	☐	Mentoring schemes	☐	Hands on interactive placement	☐
Careers academy	☐	Summer placement	☐	Other *(please specify)* ____________	☐

15. If you've done more than one, which type of activity did you enjoy **most** from those that you ticked in Question 14? **(Tick <u>one</u> only) – *If only done one type of activity, please go to question 17***

STEM days	☐	STEM Ambassadors events	☐	Master classes/lectures	☐
Competitions	☐	Attended seminars	☐	Undergraduate shadowing	☐
Taster courses	☐	Mentoring schemes	☐	Hands on interactive placement	☐
Careers academy	☐	Summer placement	☐	Other *(please specify)* ____________	☐

16. If you've done more than one, which type of activity did you enjoy **least** from those that you ticked in Question 14? **(Tick <u>one</u> only) – *If only done one type of activity, please go to question 17***

STEM days	☐	STEM Ambassadors events	☐	Master classes/lectures	☐
Competitions	☐	Attended seminars	☐	Undergraduate shadowing	☐
Taster courses	☐	Mentoring schemes	☐	Hands on interactive placement	☐
Careers academy	☐	Summer placement	☐	Other *(please specify)* ____________	☐

17. How interesting were the activities? **(Tick <u>one</u> only)** Very interesting ☐ Ok ☐ Boring ☐

18. How much awareness and knowledge did you gain about STEM related subjects? **(Tick <u>one</u> only)**

    Not at all ☐ A little ☐ Quite a bit ☐ Very much ☐

19. How much influence did this make towards your decision to take up your degree course? **(Tick <u>one</u> only)**

    Not at all ☐ A little ☐ Quite a bit ☐ Very much ☐

20. How could the activities have been improved? **(Tick <u>all</u> that apply)**

    More interaction ☐
    Better organisation ☐
    Made it more fun ☐
    Having enthusiast and engaging STEM practitioners ☐
    Providing more information about STEM subjects ☐
    Providing more information about STEM degrees ☐
    Providing more information about STEM careers ☐
    Providing more information about how STEM relates to real world ☐
    Other *(please specify)* ______________________ ☐

21. As a whole, before you started your undergraduate degree how much did you understand about the following subjects? *Please be honest* **(Tick <u>one</u> response for each subject)**

Subject	**Not at all**	**A little**	**Quite well**	**Very well**
Engineering				
Computer Science				
Mathematics				
Physics				
Chemistry				

22. In what academic year did you clearly understand what the following professions actually do? *Please be honest* **(Tick <u>one</u> response for each profession)**

Professional areas	**Before Year 6 (Primary)**	**Year 7-9 (Lower Secondary)**	**Year 10-11 (GCSE)**	**Year 12-13 (A Levels)**	**During University**	**Still don't know**
Engineers						
Computer Scientist						
Mathematicians						
Physicist						
Chemistry						

23. Do you enjoy STEM related subjects? **(Tick Yes or No)**
And then **Order** each subject with **1** being your **most** enjoyable subject and **5** the **least**.

Subject	**Yes**	**No**	**Order**
Engineering			
Computer Science			
Mathematics			
Physics			
Chemistry			

For example, I most enjoy Physics and least enjoy Chemistry;

Engineering	*3*
Computer Science	*4*
Mathematics	*2*
Physics	*1*
Chemistry	*5*

24. If you have any ideas of how we could encourage more young students to apply to study Science, Technology, Engineering and Mathematics (STEM) subjects at university then please provide details below:

Ethnicity **–**For **Question 2** please choose a **code** that best describes your ethnic group or background and **write** it in the box provided on the **first page**.

Code	**Ethnicity**
	White
1	English/ Welsh/ Scottish/ Northern Irish/ British
2	Irish
3	Gypsy or Irish Traveller
4	Any other White background
	Mixed/ Multiple ethnic groups
5	White and Black Caribbean
6	White and Black African
7	White and Asian
8	Any other Mixed/ Multiple ethnic background
	Asian/ Asian British
9	Indian
10	Pakistani
11	Bangladeshi
12	Chinese
13	Any other Asian background
	Black/ African/ Caribbean/ Black British
14	African
15	Caribbean
16	Any other black/African/ Caribbean background
	Other ethnic group
17	Arab
18	Any other ethnic group

Thank you for completing this questionnaire.

Appendix G: Medium - High Risk Research Ethics Approval

Where human participants involved in the research and/or when using primary data - Staff (Academic, Research, Consultancy, Honorary & External), Students (Research & Professional degrees) and Undergraduate or taught Postgraduates directed to complete this category of risk.

Project Title

STEM Outreach

Record of Approval

Principal Investigator

I **request an ethics peer review** and confirm that I have answered all relevant questions in this checklist honestly.	X
I confirm that I will carry out the project in the ways described in this checklist. I will immediately suspend research and request new ethical approval if the project subsequently changes the information I have given in this checklist.	X
I confirm that I, and all members of my research team (if any), have read and agreed to abide by the Code of Research Ethics issued by the relevant national learned society.	X
I confirm that I, and all members of my research team (if any), have read and agreed to abide by the University's Research Ethics, Governance and Integrity Framework.	X

Name: Yamuna Bagiya ....

Date: 29/04/2014 ....

Student's Supervisor (if applicable)

I have read this checklist and confirm that it covers all the ethical issues raised by this project fully and frankly. I also confirm that these issues have been discussed with the student and will continue to be reviewed in the course of supervision.

Name: Farzana Aslam ....

Date: 24/06/2014 ....

Reviewer

Date of approval by anonymous reviewer: ....